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THE MINERAL REQUIREMENTS OF FARM ANIMALS[1]

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IN THE last eight or ten years, much information has accumulated on the functions of minerals in the animal body, the efficiency with which minerals of feeds are utilized, the requirements of minerals for various purposes, the interactions among minerals especially in the digestive tract, the symptoms that develop when requirements are not covered by the food supply, and the best mineral supplements to use to avert deficiency diseases. The quantitative information on mineral requirements, while still very incomplete, has been extended during the period indicated.

The functions of the mineral nutrients are varied and numerous, but they may be conveniently classified under four headings:

(1) They contribute to the structure of the body. Calcium, magnesium and phosphorus are important constituents of bone. This is a growth requirement.

(2) They aid in maintaining the *status quo* of the tissues already formed against the constant erosion of the life processes. This is a maintenance requirement.

(3) They participate in the functional activities of the body, such as muscular activity. This may or may not lead to an increased requirement in the food supply. Reproduction, lactation and egg production will increase mineral requirements in proportion to the mineral content of the products formed.

(4) As integral parts of the enzyme systems in the tissues, they aid materially in metabolizing the organic food nutrients making up the bulk of farm rations.

Any detailed consideration of the functions of minerals in the animal body would be out of place in this report. However, a few salient facts about some of the so-called "trace elements," and particularly about the functions of phosphorus, may be pointed out. The trace elements known to be essential in nutrition include copper, iron, manganese, zinc, iodine and cobalt. Some of these elements are parts of the bodily machinery: iron is part of the hemoglobin molecule, zinc is a constituent of an important respiratory enzyme, carbonic anhydrase, and iodine is part of thyroxine, the active principle of the thyroid gland. The metallic trace elements are parts of the many enzyme systems that bring about the oxidation of nutritive material for the

[1] Much of the material included in this paper was presented before the Cornell Nutrition Conference for Feed Manufacturers at Syracuse, New York, on November 7, 1946.

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production of energy. A dramatic demonstration of the importance to life of these metallic trace elements is afforded by the toxic effects of cyanides. A minute dose of potassium cyanide will kill an animal in a matter of minutes. It does so by combining with the metallic component of these oxidation systems. The inactivation of the metallic ions stops oxidation in the tissues, and without oxidation, life itself ceases.

Among the mineral elements needed by the animal, phosphorus is foremost in importance. Its occurrence in bone, which holds 75 to 85 percent of the total phosphorus in the body, is of minor importance in the animal economy. It is the phosphorus in the soft tissues that is doing the yeoman's service. It participates in the metabolism of carbohydrates, fats and proteins. Where the heavy metals promote tissue oxidations, phosphorus aids in the storage of the energy produced and in its transfer in small packages to localities and reaction centers where it is needed. The discovery of this energizing role of the phosphate radical in animal metabolism is one of the most important and far-reaching discoveries of modern biochemical research. Phosphorylation and oxidation go hand in hand in providing the body with energy and in distributing it to the tissues with the least wastage as heat.

Phosphorus also seems to take part in the synthetic functions of the body, such as the production of glycogen. Recently (Rittenberg and Shemin, 1946) it has been suggested that the synthesis of body protein, involving the linking together of amino acids resulting from protein digestion, occurs only after phosphorylation. Confirmation of this suggestion is found in the experiments of Morris and Ray (1939) showing that a depression in the biological value of protein occurs in phosphorus-deficient, as compared with normal, sheep.

It is indeed strange, in view of the importance of phosphorus to the basic phenomena of animal life, that the stores of phosphorus in the skeleton are so difficult to tap when the need arises. When there is a calcium deficiency in the food supply, the calcium phosphate of the bones is readily mobilized to maintain the calcium content of the blood and tissues. The hormone of the parathyroid glands is a specific mobilizing agent for calcium and that is why the penalty of calcium deficiency in the food supply of the animal is so long deferred. No such agent exists for phosphorus. In the presence of enormous stores of phosphorus in the bones, the animal is living on a hand-to-mouth basis as far as this element is concerned. Consequently a deficient supply of phosphorus in the food soon leads to a deficient content in the blood and all the symptoms of phosphorus deficiency follow: depraved appetite, emaciation and lowered feed economy. What may be an interesting illustration of this contrast between calcium and phosphorus are the reports

of Hall and associates (1944*a*, 1944*b*) that yearling steers on a low-phosphorus ration produce beef that is "inferior to high-phosphorus beef in palatability, keeping quality and shrinkage loss," while low-calcium beef was not abnormal though on the low-calcium ration the steers produced bones of less strength.

A deficiency of phosphorus is the most prevalent mineral deficiency of cattle and sheep in this country. With these animals, the supply of phosphorus often comes largely, or entirely, from pasture herbage and from hays, which are often low in phosphorus; when the content on the dry basis is about 0.12 percent or less, roughages will not provide adequate phosphorus to the animal. If this were a calcium, rather than a phosphorus, crisis, deficiency symptoms would be deferred until, in the natural course of feeding management, the feed supply was corrected.

The requirements for minerals by growing animals can be best expressed as percentages of the dry feed consumed. This is the most practical method of expression, and it can be defended on logical grounds also. Minerals are so largely concerned in the utilization of the main organic nutrients of the ration, the carbohydrates, fats, and proteins, that the amounts of them required by the animal will parallel the amounts of organic nutrients consumed. Values for the calcium and phosphorus needs of young livestock and the way these values change as growth progresses are shown in the tables that follow. The information contained in these tables was derived by the factorial method of assessing mineral requirements used by Mitchell and McClure (1937). By this method the requirements for maintenance, growth and activity are assessed from available information, and summated to give the total net requirement in terms of animal expenditures or storages. The total requirement is then converted into feed mineral on the basis of information concerning mineral utilization, and is expressed as a percentage of the dry matter required, estimated by analogous procedures with reference to energy. Any discrepancies between the tables in this article and those of Mitchell and McClure are due to the incorporation of later more accurate information into the calculations.

The values in table 1 were obtained from information on growing Holstein heifers from birth to age at first calving, and from much less complete information on Percheron colts, collected from various sources and harmonized by mathematical means. Note that the requirements for calcium and phosphorus, expressed as percentages of the total dry feed, decrease sharply for the young calf up to about a year of age, and then more slowly. From body weights of 150 to 1200 pounds, the calcium requirement drops from 0.85 percent of the dry matter to 0.18 percent, and the phosphorus requirement from 0.52 to 0.13 percent. The calcium to phosphorus ratio also dimin-

ishes, from 1.63 to 1, to 1.38 to 1. For the later stages of growth, the calcium requirement continues to decrease, while the phosphorus requirement changes little; at maturity the calcium-to-phosphorus ratio is about 0.5 or 0.6 to 1.

In tables 2 to 4, inclusive, similar information is presented for growing and fattening swine, growing Shropshire lambs and growing White Leghorn chicks. Again, we see a decreasing intensity of the requirements for calcium

TABLE 1. CALCIUM AND PHOSPHORUS REQUIREMENTS OF GROWING HOLSTEIN HEIFERS AND PERCHERON COLTS, EXPRESSED AS PERCENTAGES OF THE DRY RATIONS

Body weight, lbs.	Age, mos.	Calcium required, pct.	Phosphorus required, pct.	Ca:P ratio
Holstein Heifers				
150	2.2	0.85	0.52	1.6
200	3.0	0.77	0.48	1.6
400	6.6	0.42	0.28	1.5
600	10.6	0.32	0.22	1.4
800	15.4	0.24	0.17	1.4
1000	21.3	0.18	0.14	1.3
1200	28.9	0.18	0.13	1.4
Percheron Colts				
440	3.1	0.67	0.41	1.6
660	5.3	0.54	0.35	1.6
880	7.9	0.42	0.29	1.4
1100	11.3	0.32	0.23	1.4
1320	15.9	0.22	0.18	1.3
1540	23.5	0.13	0.13	1.0
1760	47.6	0.06	0.09	0.6

and phosphorus with advancing age, after an initial increase (table 4) during the period of accelerating growth in the first few weeks of life; also a decrease in the calcium-to-phosphorus ratio as the intensity of bone growth decreases. The data for swine, lambs and poultry also reveal a sex difference, the necessary calcium and phosphorus percentages in the dry ration being generally larger for males than for females at all ages.

The mineral requirements for the pregnant female present a different picture than those for the growing animal, as the values for the pregnant sow in table 2 indicate. For the first half of the gestation period, the phosphorus requirements of the pregnant sow are practically unchanged, while the calcium requirements seem actually to decrease due to a declining intensity of

bone growth as maturity is approached. Only a slow increase in the requirements occurs from the 8th to the 13th week and then a somewhat more rapid increase to term. The calcium requirements increase more rapidly than the phosphorus requirements, so that the calcium-to-phosphorus ratio increases as pregnancy progresses.

Such values for the mineral requirements of animals during growth and other dynamic physiological states, as are illustrated in tables 1 to 4, inclusive, express the fact that dynamic physiological states induce parallel and variable nutritional needs. But animals cannot, in practice, be nourished in

TABLE 2. CALCIUM AND PHOSPHORUS REQUIREMENTS OF GROWING AND FATTENING PIGS AND OF PREGNANT SOWS (400 LBS.), EXPRESSED AS PERCENTAGES OF THE DRY RATIONS

Body weight, lbs.	Growing pigs								Pregnant sow			
	Age in months		Calcium required		Phosphorus required		Ca:P ratios		Week of gestation	Calcium required	Phosphorus required	Ca:P ratios
	Sows and barrows	Boars	Sows and barrows	Boars	Sows and barrows	Boars	Sows and barrows	Boars				
			pct.	pct.	pct.	pct.				pct.	pct.	
75	3.3	3.6	0.63	0.68	0.35	0.40	1.8	1.7	8	0.09	0.17	0.5
100	3.8	—	0.59	—	0.33	—	1.8	—	9	0.10	0.18	0.5
150	5.0	5.4	0.52	0.54	0.31	0.34	1.7	1.6	10	0.10	0.19	0.6
250	7.6	8.2	0.38	0.43	0.26	0.29	1.5	1.5	11	0.14	0.20	0.7
350	10.8	11.3	0.24	0.32	0.21	0.24	1.1	1.3	12	0.18	0.21	0.8
450	15.3	15.0	0.09	0.20	0.13	0.19	0.7	1.1	13	0.23	0.23	1.0
500	19.6	—	0.05	—	0.10	—	0.5	—	14	0.28	0.24	1.2
550	—	20.0	—	0.07	—	0.13	—	0.5	15	0.34	0.27	1.3
600	—	23.6	—	0.05	—	0.10	—	0.5	16	0.43	0.29	1.5

a correspondingly changing fashion. It is impracticable to change the rations of animals whenever appreciable changes occur in the requirements. It is practical to change the rations of growing animals as certain segments of the growth period are passed, but this is only an imperfect concession to the basic characteristics of the growth process. And even this concession has been made mainly with reference to protein and protein concentrate mixtures. With reference to minerals, estimates of requirements generally relate to the entire process of growth, pregnancy, lactation or egg production.

For example, many investigations on growing pullets have placed the phosphorus requirements for the entire growth period between 0.40 and 0.50 percent of the dry ration, and the calcium requirements between 0.7 and 0.9 percent. Reference to table 4 indicates that these mineral levels are adequate, or somewhat more than adequate, even for the young pullet, but are excessive for older birds. Other estimates of these minerals for the growth

of farm animals by similar long-time feeding operations are smaller than the apparent requirements for the young animal, but are excessive for the larger animal. The experiments of Aubel and associates on the calcium (1941) and phosphorus (1936) requirements of growing pigs, and the work of Beeson *et al.* on the phosphorus requirements of growing and fattening beef steers (1941) and of fattening lambs (1944) may be cited in this connection.

In experiments extending over the entire gestation period, Hogan (1932) has estimated that the rations of brood sows should contain not less than 0.4 percent of calcium for the most successful reproduction, as judged by the offspring produced and a study of the bones of the sow. Reference to table 2

TABLE 3. CALCIUM AND PHOSPHORUS REQUIREMENTS OF GROWING SHROPSHIRE LAMBS, EXPRESSED AS PERCENTAGES OF THE DRY RATION

Body weight, lbs.	Age		Ca Requirements		P requirements		Ca:P ratios	
	Males, mos.	Females, mos.	Males, pct.	Females, pct.	Males, pct.	Females, pct.	Males	Females
20	0.8	1.0	0.24	0.21	0.16	0.14	1.5	1.5
50	2.8	3.6	0.18	0.16	0.13	0.12	1.4	1.3
70	4.5	5.7	0.19	0.18	0.15	0.14	1.3	1.3
90	6.6	8.5	0.17	0.17	0.14	0.14	1.2	1.2
110	—	12.4	—	0.16	—	0.14	—	1.1
120	11.1	—	0.15	—	0.13	—	1.2	—
130	—	19.0	—	0.14	—	0.13	—	1.1
140	16.3	—	0.13	—	0.13	—	1.0	—

indicates that this value is adequate for the later stages of pregnancy, but is excessive for the early stages. However, it is probably a wise estimate to follow, in anticipation of the heavy mineral demands of lactation.

The growth requirements for calcium and phosphorus summarized in table 5 have been estimated from such data as those included in the preceding tables, tempered by information secured from properly controlled feeding experiments in which effective indices of nutritive deficiency have been applied. They are probably inadequate for the very young animal, but more than adequate for the animal approaching maturity. Hence, early deficiencies, probably manifested only in submaximal calcification of the bones, would be corrected by later excesses as maturity is approached.

The table also includes what scattered information has been found in the literature concerning the requirements for magnesium, potassium and the "trace elements," manganese, cobalt, copper, iodine and iron. Values for the growing rat have been included with those for farm animals for purposes of comparison. All values are expressed as proportions of the total dry ration, either percentages or parts per million.

The values are, of course, estimates of basic requirements, not recommended allowances. They are, also, only averages and, under the best of conditions, are subject to variation depending on the particular feeds from which the minerals are derived and upon other factors, some of which will be discussed later. Obviously, a most important dietary factor as far as calcium and phosphorus are concerned, is an adequate supply of vitamin D, either in the ration or by ultraviolet irradiation of the animal. Relatively insoluble forms of calcium and phosphorus, such as calcium sulfate or silicate, and phytic acid, are rendered available to the animal to a surprisingly high degree by an adequate supply of vitamin D.

The need for magnesium and potassium by all forms of animal life cannot be doubted. The need for manganese has been shown only for poultry and

TABLE 4. CALCIUM AND PHOSPHORUS REQUIREMENTS OF GROWING WHITE LEGHORN CHICKENS, EXPRESSED AS PERCENTAGES OF THE DRY RATION

Body weight	Calcium required		Phosphorus required		Ca:P ratios	
	Pullets	Cockerels	Pullets	Cockerels	Pullets	Cockerels
lbs.	*pct.*	*pct.*	*pct.*	*pct.*		
0.5	0.64	0.71	0.32	0.36	2.00	1.97
1.0	0.70	0.86	0.35	0.43	2.00	2.00
1.5	0.68	0.86	0.34	0.43	2.00	2.00
2.0	0.59	0.78	0.31	0.39	1.90	2.00
3.0	0.39	0.66	0.25	0.34	1.56	1.94
4.0	—	0.42	—	0.28	—	1.50

for the rat and the mouse. The evidence for the pig is doubtful (Johnson, 1944). However, the activating effect of manganese on various tissue enzymes. particularly arginase, suggests strongly that it is an essential mineral throughout the animal kingdom. Cobalt has been shown to be required by ruminants only, and the symptoms of its deficiency have been described (Russell, 1944; Green, 1939). Copper and iron seem to be required by all animals thus far studied. It is a curious fact that in spite of all the nutrition investigations carried out on iron metabolism, so little is known of the quantitative requirements. The one value given in table 5 for the rat was obtained in our own laboratory and may well be too high (Mitchell and Hamilton, 1934–35).

The values in table 5 relate to the growing animal. For the pregnant female, the requirement for calcium on the basis of the necessary concentration in the dry ration over the entire gestation period does not seem to be appreciably higher than that for growth. The requirement for phosphorus is definitely higher (Beeson *et al.*, 1945), about 40 percent higher in the case of the ewe. For lactation the requirement for calcium expressed as a percentage

of the dry ration, is not elevated above the requirement for growth except at high levels of milk production, because the total requirement of food energy increases so much in milk production. The requirement for phosphorus will be elevated, however. Thus, a 1000-pound cow producing 40 pounds of 3.5 percent milk requires 0.27 percent calcium in its dry ration and 0.26 percent phosphorus. The former value is the same as that given in table 5 for growth, while the latter value is somewhat more than a third higher than the indicated phosphorus required for calf growth given in table 5. According to Beeson and his associates, the lactating ewe requires 0.23 percent phosphorus on the air-dried ration, a value one-half again as high as that required for growth.

In egg production the phosphorus requirement, while, of course, greater than that of the non-laying hen, may not be higher than that indicated for

TABLE 5. ESTIMATED AVERAGE REQUIREMENTS[1] OF MINERALS BY GROWING ANIMALS, EXPRESSED AS PERCENTAGES OF THE DRY RATION UNLESS OTHERWISE SPECIFIED

Mineral	Rat	Pig	Chicken	Calf	Lamb	Horse
Calcium	0.36	0.40	0.66	0.27	0.18	0.23
Phosphorus	0.22	0.30	0.40	0.19	0.15	0.21
Magnesium	0.005		0.04	0.07		
Potassium	0.17	0.15	0.17			
Manganese			0.0040			
Cobalt				0.07[2]	0.07[2]	
Copper	3[2]	<8[2]		3[2]	5[2]	
Iodine			1[2]	0.09[2]	0.11[2]	
Iron	60[2]					

[1] The indicated requirements will not take care of the very young animal.
[2] p.p.m. on the dry ration.

growth in table 5 (Mitchell and McClure, 1937; Evans, Carver and Brant, 1944*a*). The calcium requirement is very much higher, rising to 3.00 percent or more of the ration, depending upon the rate of egg production (Mitchell and McClure, 1937; Gutowska and Parkhurst, 1942b; Evans, Carver and Brant, 1944*b*). However, regardless of the level of calcium in the ration, the high-producing hen withdraws calcium from her skeleton, later to be replaced as the rate of egg production declines. There seems to be little or no advantage in increasing the calcium content of the hen's ration above 3 percent. The necessary concentration of manganese in the ration of the laying hen does not seem to be higher than that in the ration of the growing chick (Lyons, 1939; Gutowska and Parkhurst, 1942a).

Muscular work, according to Harvey *et al.* (1943), does not increase the

requirements of Percheron geldings for either calcium or phosphorus. However, exercise may increase the requirement for potassium (Follis, 1942).

It is of interest to compare the mineral requirements listed in table 5 with published analyses of the mineral contents of animal feeds expressed on the dry matter basis. It would be difficult to prepare a practicable ration, reasonably well-balanced in other respects, that would contain inadequate amounts of potassium or magnesium (see Mitchell and McClure, 1937, Appendix table 1). The same is true for copper, cobalt, iron and iodine except in restricted areas where the soils, waters and forage crops are deficient in one or other of these elements. In such areas special measures to combat mineral deficiencies are required. In poultry rations, especially if based largely upon corn, the manganese content may well be less than that required. For other classes of livestock, however, there is no reason to suspect manganese deficiency in practical rations.

Turning, now, to calcium and phosphorus, undoubtedly special attention must be paid to these elements in balancing farm rations, because many feeds are deficient in them. Grains and grain products as a class are inadequate in calcium, but less often inadequate in phosphorus. Protein concentrates of plant origin are again inadequate in calcium but adequate in phosphorus, while those of animal origin, to the extent that they contain bone, are rich in both calcium and phosphorus. Legume forage and hay crops are rich in calcium, but of variable phosphorus content depending on the content in available phosphorus of the soils upon which they are grown. Non-legume pasture crops and hays are not particularly reliable sources of either calcium or of phosphorus, again depending upon soil conditions.

Let us consider the phosphorus situation at greater length. By combining protein concentrates with grains and grain products to produce rations and grain mixtures containing adequate levels of protein for livestock, the phosphorus content of the mixture is generally raised above 0.3 percent and may be raised considerably above 0.4 percent. The requirements of growing animals for phosphorus, except for the very young animal, are mostly less than 0.3 percent and reach 0.4 percent only for the chicken (see table 5).

Now there is a close relationship between the requirements of animals for phosphorus and the requirements for protein (Mitchell, 1943). In very early growth, about 0.04 lb. of phosphorus is required per pound of protein required, while in the fully grown animal the ratio is approximately 0.02 lb. of phosphorus or less per pound of protein. Since in the egg, the ratio of phosphorus to protein is 0.0154 to 1, and in 3.5 percent milk, 0.0249 to 1, one would not expect that egg production in the hen or milk production in the cow would raise the ratio of phosphorus required to protein required beyond this range. In the cereal grains the ratio of phosphorus to protein varies on

the average from 0.027 to 0.033 lb. of phosphorus to each pound of protein, and in the vegetable protein concentrates the phosphorus-to-protein ratio varies from 0.015 to 0.030 to 1. In animal protein concentrates containing considerable bone, the ratio may be very much higher than these. Such considerations would lead to the conclusion that, if the protein in a growing ration is raised to an adequate level by the proper combination of available feeds, the phosphorus content may be simultaneously raised to an adequate level in most cases, without the need of a mineral supplement. Possibly the very young chick or pig would be exceptions to this statement, if animal protein feeds of high ash content are not used.

When mineral supplements are required, the choice should of course be made among those minerals known to be highly available to the animal. Among the supplements of calcium and phosphorus, steamed bone meal and dicalcium and tricalcium phosphates are standards. Among the mineral calcium phosphates, raw rock phosphate cannot be recommended because of its high content of fluorine. The defluorinated products made from rock phosphate, quite aside from their content of fluorine, are of widely different values. Defluorination by the fusion process has yielded the more satisfactory products with availabilities to animals approaching or equalling bone meal in this respect. Defluorination by the superphosphate procedure, involving calcination and treatment with acid, yields less satisfactory products and less uniform products. Many of them are poorly utilized by the animal, probably because of their content of calcium metaphosphate. The phosphorus of calcium metaphosphate is only about 70 percent as available to the growing rat as the phosphorus of dicalcium phosphate. A close correlation seems to exist between the availability of the phosphorus in these calcium phosphate preparations and their solubility in dilute hydrochloric acid. Reynolds, Hill and Jacobs (1944) have developed a simple laboratory test that appears to be reliable in distinguishing phosphates of low from those of high availability.

A wide variety of calcium supplements, other than phosphates, are valuable in animal feeding, including the carbonate, the sulfate (gypsum), the gluconate, and even some of the silicates. It should be noted again that the full value to the animal of all calcium and phosphorus supplements, but particularly of the less soluble ones, is realized only when the ration contains adequate amounts of vitamin D or when the animal is exposed to adequate amounts of ultra-violet irradiation, as by exposure to sunlight. The means by which vitamin D accomplishes this miraculous feat is not numbered, unfortunately, among the nutritional discoveries of the last eight or ten years.

The fluorine content of rock phosphates and products made from them constitutes a hazard to the use of such supplements. Rock phosphate, or-

cinarily containing 3 to 4 percent of fluorine, is definitely unsafe for all classes of livestock in the amounts that would serve as an affective ration supplement. Defluorinated phosphates containing 0.1 percent or less of fluorine are reasonably safe. The fluorine content of the ration containing the supplement should not exceed 0.01 percent for swine, cattle and sheep, nor 0.05 percent for poultry. Possibly these limits are too high over a period of years for breeding stock and for dairy cattle (Mitchell, 1942).

The requirements of farm animals for sodium or chlorine, or both, may not be covered by rations made up largely or entirely of plant products. A common recommendation is the inclusion of 0.5 percent salt in the grain mixture of cattle and sheep. Certainly, larger proportions are not to be recommended. In those areas of the country where iodine deficiency is endemic, the use of iodized salt in the above proportions is advisable. As little as 0.01 percent of potassium iodide in the salt, if precautions are taken to stabilize the iodide, is all that is needed (Griem *et al.*, 1942).

In balancing rations for farm animals, it is a wise procedure to set the mineral content above the estimated requirements. A reasonable margin of safety is good practice. But there is a limit to such a procedure, since a margin of safety will merge into a nutritional hazard. Many of the nutritionally essential minerals, such as manganese, copper and cobalt, are toxic above certain low levels, or possess undesirable physiological effects. Also, interactions occur among minerals in the digestive tract, whereby one mineral will precipitate another in an insoluble form, such as a soluble phosphate and a soluble salt of iron or aluminum, or a metal may be immobilized by adsorption on an insoluble mineral precipitate. Even excess salt intake has its hazards: it may lower the iodine content of the thyroid gland (Sharpless and Anthony, 1943), or lead to edema and ascites (Scrivner, 1946).

The element calcium seems to possess to a preeminent degree the property of disturbing the assimilation of other minerals. Its relation to phosphorus assimilation is well known. The utilization of phytic acid in particular is impaired by calcium to phosphorus ratios of 2 to 1 or higher. Many salts of calcium greatly reduce the assimilation of iron, while high ratios of calcium to phosphorus produce the same effect. Excess calcium in the diet of chicks depresses the assimilation of manganese. In a similar manner, an excess of calcium will impair the assimilation of iodine. In the same vein, excessive liming of the soil is deprecated, because it may reduce the content of trace elements in pastures and forage crops. However, these effects of excess dietary calcium in the diet may tend to counteract the deleterious effects of high levels of iodine, of lead and of fluorine.

It is important to assure an adequate mineral supply in the rations of farm animals; otherwise an impairment of appetite, an inefficient use of food

will result, followed by pathological symptoms and then death. But the mineral content of the ration should be kept as low as possible, not only because of the deleterious effect of excesses, and of the immobilizing of essential elements in insoluble precipitates, but also because minerals contribute no food energy to the animal. The higher the ash content of a ration, the lower its energy value. Farm animals must have minerals, but minerals in moderation.

Summary and Conclusions

The functions of minerals in nutrition are briefly discussed, particularly the omnipresent role of phosphorus with reference to all organic nutrients. Tables of the requirements of animals for calcium and phosphorus, derived by a factorial method of assessing each item in the total requirement, are presented, demonstrating the changing requirements as functional states change. The effect of species, age, sex and function (maintenance, growth, gestation, lactation and egg production) on requirements expressed as proportions of the dry matter consumed are considered. The requirements for other minerals than calcium and phosphorus are assessed in so far as available information will permit.

A comparison of mineral requirements with the occurrence of minerals in feeds reveals the likelihood of the occurrence of mineral deficiencies in livestock feeding. When mineral supplements are required, the type of supplement to use, particularly with reference to fluorine hazard, is discussed. The interactions of minerals in the digestive tract and the dangers of excessive concentrations of minerals in rations are pointed out.

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EFFECT OF FEEDING LEVEL AND LIVEWEIGHT ON DAILY GAINS OF PIGS

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IN A previous paper (Headley, 1946) the writer introduced an equation showing the effect of the feeding level on the daily gains of pigs from weaning age to approximately 200 pounds. According to that equation, daily gain is equal to .367 times feeding level plus a constant of 0.2. The study dealt with the effect feeding level has on the whole range of growth between the stated liveweight intervals but it does not apply to small segments of growth-feed relationships.

Objective, Procedure and Results

Subsequent analysis of the data made it possible to express in mathematical terms, the effect of feeding level on daily gains of pigs within comparatively small liveweight intervals and from these, a single equation was found applicable to all feeding levels from weaning to 200 pounds.

In the solution of the problem, regression equations were first calculated to indicate the effect of feeding level on daily gains of pigs with mean liveweight intervals occurring within the following limits: (a) under 50, (b) 50.1 to 75, (c) 75.1 to 100, (d) 100.1 to 150, and (e) 150.1 to 200 pounds.

The data used in this study were derived from experiments conducted by the Nevada Agricultural Experiment Station through the years 1926 to 1945.

Throughout the experiments,[2] the groups were weighed at 2-week intervals and a continuous record of feed consumption was kept. The result from each 2-week feeding test was included in its proper classification as to mean liveweight.

Since the amount of forage derived from pasture was unknown and could not be closely estimated, the nutrients from roughage fed in dry lot feeding experiments were also omitted in order to make the two sets of data fully comparable. The equations express the relation of the feeding level of concentrates (including skim milk) to daily gains. By feeding level, as the term is here used, is meant the percentage that the total digestible nutrients fed per day (excluding roughage) is of the mean weight of the pigs.

Regression equations fitting the data pertaining to each weight class are

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[2] The experiments were conducted on the Newlands Field Station, Fallon, Nevada, by the Nevada Agricultural Experiment Station in cooperation with the Division of Soils, Fertilizers, and Irrigation (formerly the Division of Western Irrigation Agriculture) of the Bureau of Plant Industry of the U. S. Department of Agriculture.

given in table 1, and were used to construct the trend lines in section A of the chart.

Daily gains increased with the feeding level and with the growth of the pigs. The effect of the feeding level on daily gain is indicated for each liveweight interval by the regression equations in table 1, and figure 1 (A). Each

TABLE 1. RELATION OF DAILY GAINS OF PIGS TO FEEDING LEVEL

Class	Experimental groups, number	Weight intervals, lbs.	Mean weight, lbs.	Feeding level, X	Mean daily gain, lbs.	Regression equation, $a+bX$	Standard error, $\overline{S}yx$	Correlation coefficient, r_{xy}
A	99	under 50	42.0	2.42	.62	.190+.178X	.154	.667
B	171	50.1 to 75	62.0	2.66	.87	.224+.242X	.194	.692
C	138	75.1 to 100	86.9	2.72	1.04	.337+.258X	.164	.740
D	241	100.1 to 150	124.7	2.85	1.24	.145+.386X	.212	.727
E	196	150.1 to 200	175.5	2.99	1.46	.392+.356X	.245	.574

percent increase in feeding level increased daily gain by amounts which varied according to the liveweight of the pigs.

It may be seen from the slopes of the lines in figure 1 (A) that the regression equations were reasonably consistent, except that class D, representing pigs weighing within the limit 100 to 150 pounds, does not have a slope conforming well to that of the other lines.

The constants and regression coefficients generally increase as the pigs become heavier but it will be noted that there are some irregularities which no doubt originated from incomplete or inaccurate data. It is probable that irregularities would be diminished if the data were to be derived from experiments designed primarily to obtain these relationships.

The individual regression equations in table 1 show only the relationship between feeding level and daily gain for short weight intervals, each weight interval requiring a separate equation for its solution which would be awkward to apply in actual practice. To meet this difficulty, a single equation has been derived which takes into consideration the effects of both weight and feeding level on the daily gain of pigs.

There is a straight line relationship between feeding level and daily gain. The liveweight effect on daily gain closely approximates the logarithm of 1/10 the weight, expressed as (log W/10).

In figure 1 (A) the regression lines best fitting the available data are shown by themselves. As mentioned before, some irregularities are to be noticed in the pitch of the lines, especially line D which represents pigs weighing between 100 and 150 pounds. In figure 1 (B), it will be observed that the irregularities have disappeared. In this section the regression lines were calculated by the new equation.

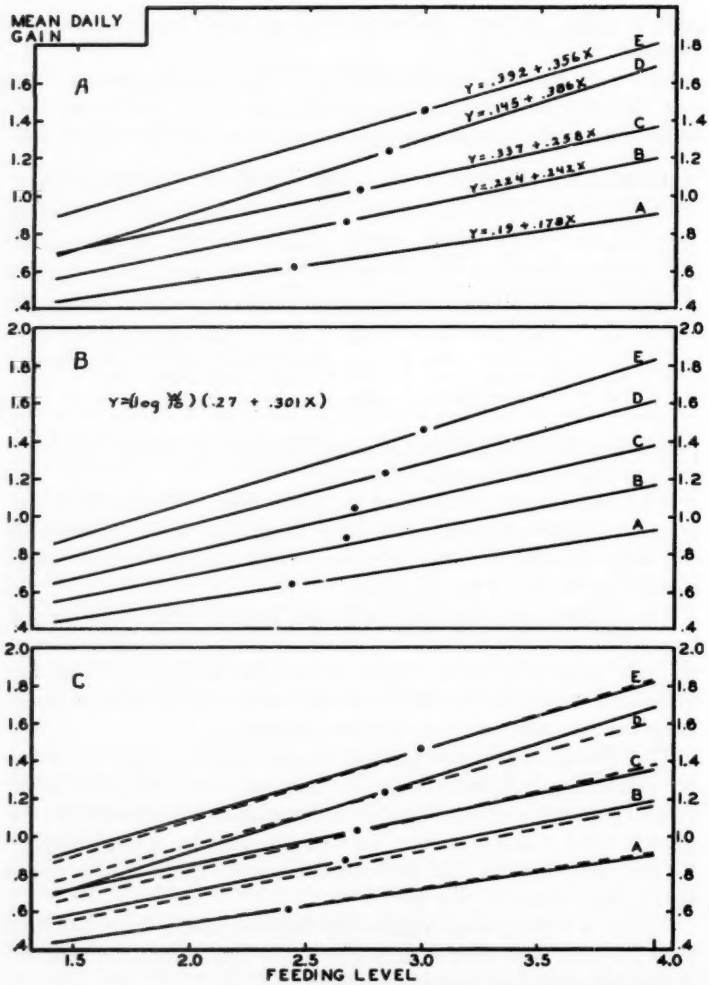

Figure 1. Regression lines showing effects of feeding level on daily gains of pigs for different liveweight intervals. (A) Lines drawn according to regression equation for each liveweight interval based on actual experimental data. (B) Regression lines drawn according to equation (1). (C) Lines in A and B superimposed. If it is logical to assume that pigs have a uniform growth pattern from weaning to maturity under uniform feeding conditions, then line D in section A should have a decidedly smaller pitch and line C should have a slightly greater pitch. The pitch of the lines becomes consistent when the equation in B is used.

$$\text{Daily gain} = (\log W/10)\,(.27+.301X) \qquad (1)^3$$

in which W represents weight and X represents feeding level.

In the lower section (C), the two sets of lines are superimposed to facilitate comparison. The new equation has the effect of normalizing the pitch of the lines, which probably come closer to representing true values than the original regression lines. There are very slight differences (table 2) between actual mean daily gains and the mean daily gains estimated by equation (1). It will be observed that the differences between estimated and actual daily gain were obtained only in classes (B) and (C) and that these differences are insignificant, amounting to .02 pound in each case.

The method of making the calculations is shown in table 2, in which the essential data in columns 2 and 3 awere brought forward from table 1.

TABLE 2. ESTIMATION OF DAILY GAIN FROM MEAN WEIGHT AND MEAN FEEDING LEVEL

Class	Mean weight, lbs.	Mean feeding level, lbs.	Log W/10	Feeding level factor, .27+.301X	Estimated daily gain,* lbs.	Actual mean daily gain, lbs.
A	42.0	2.42	.623	1.00	.62	.62
B	62.0	2.66	.792	1.07	.85	.87
C	86.9	2.72	.939	1.09	1.02	1.04
D	124.7	2.85	1.096	1.13	1.24	1.24
E	175.5	2.99	1.244	1.17	1.46	1.46

* Estimated daily gain = column 4 times column 5.

Application of Results

When the average total digestible nutrients fed per day and the mean liveweight of any group of pigs is known, it is possible by means of equation (1) to calculate an estimated daily gain which may be looked upon as a standard or norm. If the actual daily gain is taken as a percentage of the norm, a factor is obtained which should be useful in judging the efficiency of rations in respect to variations in values arising from other factors than the total digestible nutrient content of the feeds. The use of the equation is presumed to eliminate the effects of differences in liveweight and total digestible nutrients. Then variations in gain which still have taken place are attributable in part to differences in the quality and quantity of protein, variations in the composition of feeds not included in the calculation of digestible nutrients but which do affect their feeding values. Other causes of variations in gains

[3] Equation (1) was found by charting daily gains against the weight of pigs at six feedings levels. The curve of log W/10 corresponded well with the curvature of the six lines, but its position needed adjusting by multiplying by factors which were found to have a straight line relationship to the feed level as expressed by the term (.27+.301X).

may be due to differences in pastures, breeds, breeding, inherited characteristics of the individual animals used in the experiments, and other management factors.

For illustration, basic data from Edwards, 1930, have been used in table 3 to show how "percent efficiency" may be used to interpret results.

Groups 1 and 3 received the same kind of grain ration, namely, corn, tankage and linseed meal, but group 1 was on alfalfa pasture and group 3 on rape pasture. The respective daily gains of the two were 1.26 and 1.43 pounds. The rape pasture might appear to be superior to alfalfa except for

TABLE 3. COMPARISON OF RELATIVE EFFICIENCY OF RATIONS

Ration		Mean weight, W	Daily gain, G	TDN per day, N	Feeding level, X	Log $W/10$, L	$.27+.301X$, F	Norm, LF	Efficiency %, G/LF
Concentrates*	Roughage								
CTLm	Alf. past.	122	1.26	3.47	2.84	1.09	1.12	1.22	103
BO	Alf. past.	120	1.24	3.90	3.25	1.08	1.25	1.35	92
CTLm	Rape past.	125	1.43	4.21	3.37	1.10	1.28	1.41	101
BTLm	Rape past.	125	1.36	4.09	3.27	1.10	1.25	1.38	99
BO	Rape past.	124	1.34	4.23	3.41	1.09	1.30	1.42	94

* C = corn, T = tankage, Lm = linseed meal, B = barley, O = oats.

the fact that the pigs on rape received a materially higher grain ration than those on alfalfa. The question is, which would have made the greater gains if they had been fed at the same feeding level in respect to grain?

The estimated percent efficiency represents a ratio of actual to estimated gains. By the application of equation (1) it is found that the efficiency of the two groups is 103 and 101 percent respectively. It is therefore not justifiable to conclude that rape is more efficient than alfalfa in producing gains when the pigs are fed at the same feeding levels. In like manner it is found that the efficiency of group 4 over group 5 is greater than would appear by comparison of daily gains alone.

Efficiency of rations have been calculated for a considerable number of experiments conducted by the four experiment stations listed in table 4. The comparatively low efficiency of the Utah rations appears to have been due to the use of barley instead of corn as the basic ingredient and that nearly one third of the groups received no protein supplement. Both of these factors appear to affect the efficiency of utilization of nutrients.

In comparing ratios of one state with another, there appeared to be differences in the relative efficiency of similar or identical rations, presumably due to differences in the biological values of the same kinds of feeds produced on different soils or to climatic conditions. For instance, the basic ration of corn

and tankage in Kansas was significantly more efficient than the same ration in other states where comparisons were made. Is the biological value of Kansas corn and roughage superior to the corn and roughage produced in the other states where nutrients have been depleted to a greater extent from the soil by a relatively long period of farming?

Percent efficiency is presumed to be independent, within limits, of the weight of pigs or level of feeding, but it is not independent of the biological values of the feeds and may therefore be used to determine relative biological values. It is not known how well the logarithmic relationship for liveweight or the feed factor holds for weights in excess of 200 pounds.[4]

TABLE 4. AVERAGE EFFICIENCY PERCENTAGES OF EXPERIMENTS CONDUCTED BY THE KANSAS, MICHIGAN, OHIO AND UTAH STATIONS

Station and reference	Number of experiments	Mean percent efficiency
Kansas—Aubel *et al.* (1937, 1941)	115	104
Michigan—Edwards (1930)	36	98
Ohio—Robison (1935, 1942)	81	98
Utah—Smith *et al.* (1935)	28	93

Summary

The data used were derived from experiments in swine feeding conducted during the period 1926 through 1945. The objective in mind when working over these experiments was to determine the effect of feeding level on daily gains. By feeding level is meant the percentage total digestible nutrients fed per day is of the mean weight of the pigs. Regression equations to indicate the effect of feeding level on daily gain were first calculated for five liveweight intervals as follows: (1) under 50 pounds; (2) 50.1 to 75 pounds; (3) 75.1 to 100 pounds; (4) 100.1 to 150 pounds, and (5) 150.1 to 200 pounds.

With the possible exception of number 4, the regression coefficients were found to be reasonably consistent. The equations however, would be difficult to apply in practice because data usually jump across any arbitrarily drawn liveweight intervals. From them an equation was derived indicating the effect of both feeding level and weight on daily gain of pigs.

$$\text{Daily gain} = (\log W/10)\,(.27+.301X).$$

[4] Results of compilation of data from other stations, made too late to correct text, indicate that equation (1) is not well adapted to finishing weights of pigs much above 200 pounds. The efficiency of pigs in the Kansas experiments appears higher than those of other states because the finishing weights of nearly all groups were well above 200 pounds.

The relationship between daily gain and feeding level is straight line, but that between daily gain and liveweight is curvilinear. When using the equation, results may be taken as a standard or norm by means of which the efficiency of a ration can be judged. By its use, the effects of differences in liveweight or feeding level of groups under comparison may be eliminated. Differences in the biological value of combinations of feeds may be expressed as a percentage of expected values. Results from the Kansas, Michigan, Ohio, and Utah Experiment Stations were used to illustrate how the equation may be applied to feeding problems.

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METHODS OF FEEDING SOYBEANS AND THEIR SUPPLEMENTATION IN A HOGGING-OFF PROGRAM[1]

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SOME soybeans, which are grown extensively in eastern North Carolina, may be left in the field because of shattering during harvesting. Pigs may be used to salvage them, or the entire crop may be "hogged off" when this procedure is more economical. This "hogging off" saves the labor of harvesting and utilizes the beans that would otherwise be lost. The soybean diets usually fed to pigs (Shrewsbury and Vestal, 1943) require mineral supplements of calcium and phosphorus; however, it is not known whether a protein supplement is needed to produce better gains in weight. Vestal (1930) has shown that raw soybeans are equal to tankage as a protein supplement to corn for growing and fattening pigs on pasture. On the other hand, Mitchell and Smuts (1932) have shown them to be deficient in cystine. The results reported in this paper are based on the feeding of raw soybeans rather than on processed soybean meal.

Hostetler *et al.* (1939) have shown that pigs of initial weights of 40 and 60 pounds make satisfactory gains to weights of 80 to 100 pounds, respectively, when fed supplemented peanut diets. These diets consisted of peanuts, animal protein, alfalfa meal, a mineral mixture of calcium carbonate, steamed bone meal, and salt; and were fed until the animals reached the weights indicated above. Then a hardening diet containing corn, 13 percent cottonseed meal, animal protein, alfalfa meal, and mineral mixture, was fed until they reached 225 pounds in weight. This procedure of feeding resulted in the production of firm carcasses.

One hundred and fifty-three 60-pound pigs were fed supplemented soybeans both individually and in groups (Hostetler and Halverson, 1940). The diets of 30, 40 and 50 percent soybeans supplemented with corn, animal protein, alfalfa leaf meal, and mineral mixture were fed until the animals reached a weight of 100 pounds. They were then fed a hardening diet of 75 percent corn, 13 percent cottonseed meal, 5 percent each of animal protein and alfalfa leaf meal, and 2 percent mineral mixture to a weight of 225 pounds. The gains in weight of these pigs varied inversely with the amounts of soybeans

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in the diets fed; however, the gains were satisfactory on the hardening diet with 97 percent of the carcasses grading firm.

The work reported here is a continuation of feeding pigs, individually, diets high in soybeans as reported by Hostetler and Halverson (1940). The first objective of this study was to find whether a supplement of other protein concentrates is desirable or necessary with diets composed largely of soybeans. The second objective was to determine whether satisfactory gains and firmness of carcass could be obtained with such diets when pigs weighing about 40 pounds were fed, individually or in groups, until they weighed 85 pounds and then fed a hardening diet of corn supplement with cottonseed meal.

Experimental Procedure, Results and Discussion

Group Feeding.

Five groups of 10 pigs each, C to G, having an initial average weight of 41.4 pounds, were fed in five trials from 1937 to 1942. Two groups, D and F, "hogged off" soybeans. Group F was self fed a mineral mixture while group D was fed a protein supplement, which included a mineral mixture, at the rate of 0.5 pound daily per pig (table 1). Two other groups, E and G, were

TABLE 1. MINERAL MIXTURE AND PROTEIN SUPPLEMENT FED TO PIGS IN FIVE TRIALS

Mineral mixture		Protein supplement	
Constituent	Percent	Constituent	Percent
Calcitic limestone	40.0	Fish meal, 60% protein	50
Steamed bone meal	40.0	Cottonseed meal, 36% protein	20
Common salt	17.5	Alfalfa leaf meal	25
Copperas	2.4	Mineral mixture	5*
Copper sulphate	0.1		
Total	100.0	Total	100

* The amount of minerals supplied by the protein supplement per pig daily was considered adequate.

hand-fed in dry lot all the raw soybeans that they would consume in order to equal the gains in weight of groups D and F, respectively. Group E, like group D, received 0.5 pound of protein supplement per pig daily and group G was also self-fed a mineral mixture like group F. A fifth group, C, was hand-fed sufficient corn supplemented with 0.5 pound of protein concentrates per pig daily to yield an expected average daily gain equal to that of group D, the actual gains being 0.75 and 0.67 lb. (see table 3).

Individual Feeding

Groups A and B of five pigs each, averaging 42.8 pounds, were hand-fed in five trials, respectively, 58.5 and 78.5 percent raw ground soybeans in supplemented diets 1 and 2 which contained 6.5 percent cottonseed meal and 2.5 percent mineral mixture (table 2). These pigs were fed individually on a concrete floor. When they reached an average weight of 85.2 pounds, they were changed to the hardening corn diet No. 3, which contained 13 percent cottonseed meal. This individual feeding is a continuation of a study in feeding diets composed largely of soybeans (Hostetler and Halverson, 1940).

TABLE 2. DIETS FED IN ALL FIVE TRIALS

Ingredients	Diet and group		
	1 A	2 B	3* A to G
	percent	*percent*	*percent*
Raw soybeans, ground	58.5	78.5	—
Yellow corn, ground	20.0	—	72.0
Fish meal, 60% protein	5.0	5.0	5.0
Cottonseed meal, 36% protein	6.5	6.5	13.0
Alfalfa leaf meal	7.5	7.5	7.5
Mineral mixture (table 1)	2.5	2.5	2.5
Total	100.0	100.0	100.0
Protein, estimated	30.7	36.2	16.5

* Diet No. 3 fed to all pigs during second period.

Both Individual and Group Feeding

All pigs in each trial or experiment were of known age and breeding and had been uniformly fed and managed under the supervision of the North Carolina Agricultural Experiment Station. They were dewormed before being placed on the experimental diets. Most of the pigs used were of medium type and all were purebred. In the first trial (1937) all pigs were of the Poland China breed, in the next three trials (1938, 1939 and 1940) both Duroc and Poland China pigs were used and in the final trial (1941) all pigs were of the Duroc breed.

The pigs of all groups averaged 42.1 pounds at the outset and were fed to an average weight of 85 pounds (period 1). At that time, they were changed to the hardening diet No. 3, consisting of corn, fish meal, cottonseed meal, alfalfa leaf meal, and mineral mixture, which was then fed until

the pigs reached marketable weight, an average of 225.6 pounds (period 2). The pigs were slaughtered by the Bureau of Animal Industry at Beltsville, Maryland, and the carcasses were held in the cooler at the proper temperature (33 to 35° F. in so far as possible) for 48 to 60 hours, then graded for quality and firmness of carcass. Samples of back and leaf fat were taken from each carcass for the determination of the fat constants, refractive index, iodine absorption number by the Hanus method, and melting point.

The Tokyo variety of soybeans was fed in dry lot and "hogged off" in the field. When the yield of soybeans in the field was insufficient for the pigs to reach 85 pounds in weight, dry beans were supplied by scattering them on the ground. The yield of soybeans in the fields "hogged off" was estimated by harvesting yard-square samples at regular intervals over the field. An average of 15 such areas were harvested per acre; on irregular stands, more areas were sampled. Either No. 2 or No. 3 grade of yellow corn was fed. The alfalfa leaf meal used had a bright pea green color.

Proportional samples of feed from each 100 pounds of mixture were taken and composited at the end of each feeding trial. Likewise, representative check samples of corn and soybeans fed in each trial were obtained. These samples were analyzed for moisture, crude fat, and total starch.

The results of these feeding trials are summarized for each group in tables 3 to 6.

Discussion

Gain in Weight. In "hogging off" soybeans, group D, fed the protein supplement containing a mineral mixture, gained 0.75 pound per day or 0.08 pound more than group F, which received mineral mixture alone (table 3). Correspondingly, the hand fed pigs group E, receiving protein supplement, gained 0.06 pound per pig per day more than group G which was self-fed mineral mixture and after the first year was also hand fed alfalfa leaf meal.

Group G, which was hand-fed soybeans in dry lot plus a mineral supplement and alfalfa leaf meal, had the lowest average daily gain. Seven and five-tenths percent alfalfa leaf meal was added to the diet after the first year of feeding because of the failure of the pigs to gain. This failure to gain was attributed to the lack of sufficient vitamin A in the diet. One pig died, four were discontinued at the end of the soybean feeding period, and the five remaining pigs made subnormal gains. The data obtained from this group for the first year's feeding were not used in the summary of the five trials.

On the hardening diet groups F and G, in which mineral mixture had constituted the only supplement for soybeans, made significantly greater daily gains than the protein supplemented groups D and E, and the corn-fed group C. For the total feeding period, however, group F made essentially

the same average daily gain as the protein supplemented group D. During the hardening period, the increased daily gains by the dry lot fed Groups E and G, were not large enough to equal the average daily gain for the entire feeding period of the "hogging off" groups D and F, or that of the corn-fed group C.

TABLE 3. AVERAGE WEIGHTS AND GAINS PER PIG FOR SEVEN GROUPS OF PIGS FED IN FIVE SEPARATE TRIALS[1]

Group	No. of pigs	Lbs. weight, period			Days fed, period			Lbs. daily gain, period		
		First		Second						
		Initial	Change	Final	First	Second	Total	First	Second	Total
Group D "hogged off" soybeans with protein supplement and mineral mixture checked by Group E dry lot										
D	50	43.0	85.5[2]	224.7	58.0	77.9	135.9	0.75	1.80	1.35
E	50	42.0	85.0	223.2	73.6	74.8	148.4	0.58	1.85	1.24
Group F "hogged off" soybeans with mineral mixture self-fed, checked by group G dry lot, hand-fed										
F	50	40.9	84.9	225.8	65.6	73.4	139.0	0.67	1.92	1.33
G	40[3]	41.4	84.6	224.7	83.3	71.5	154.8	0.52	1.96	1.19
Control group C, hand-fed in dry lot, corn diet, restricted to equal the gain of group F										
C	50	42.1	85.3[4]	226.3	63.9	76.2	140.1	0.67	1.85	1.31
Group A and B individually fed 58.5 and 78.5 percent soybeans in supplemental diets										
A	25	43.1	85.4	224.1	53.6	83.1	136.7	0.79	1.67	1.34
B	25	42.5	85.0	223.7	70.9[5]	79.4	150.3	0.60	1.75	1.18

[1] Least significant difference for "hogging off" versus hand-fed and supplement versus mineral mixture: Groups D, E, and F, G; first period, 0.078; second period, 0.080. Least significant difference between any two groups of D, E, F and G, first period 0.110; second period 0.113; for groups A and B in first and second periods 0.108 and 0.144, respectively. Least significant difference for comparing groups A or B with the average of any two groups of D, E, F and G, first period 0.095; second period 0.116.

[2] 49 pigs placed on hardening diet; 45 pigs completed the test.

[3] 10 pigs not included for 1937–38.

[4] 50 pigs placed on hardening diet; 49 completed the test.

[5] Does not include 147 days for Pig No. 6, 1941–42.

Group A, receiving 20 percent corn and 58.5 percent soybeans in the protein supplemented diet, made a greater average daily gain by 0.19 pound than group B, which received 78.5 percent soybeans in a similar diet without corn. Group B did not eat appreciably more soybeans per day than group A, averaging 1.6 pounds per pig compared with 1.5 pounds daily per pig in group A, showing that they did not relish so much beans in the diet. This may in part be caused by the approximately 0.2 pound of beany-flavored oil consumed in the 1.6 pounds raw soybeans.

The average daily gain in weight of these two groups decreased as the amount of soybeans in the diet increased as has been shown previously (Hostetler and Halverson, 1940). Thirty, forty, and fifty percent soybeans in the diet were fed with an average daily gain of 0.83, 0.74, and 0.65 pound, respectively, compared with 0.79 and 0.60 pound for the groups A and B in the present study.

Retarded Growth. There is another aspect to the gains of pigs made by feeding soybeans. Biweekly weights of all groups of pigs showed a depressed

TABLE 4. AVERAGE FEED CONSUMPTION PER PIG FOR SEVEN GROUPS OF PIGS FED IN FIVE SEPARATE TRIALS

Items compared	Group and pig numbers						
	A 1–5	B 6–10	C 11–20	D 21–30	E 31–40	F 41–50	G 51–60
1st period diet consumed, lbs.	132.7	162.0	125.9	198.4	151.9	160.9[1]	162.6
Total soybeans consumed, lbs.	77.6	133.4	—	164.7	121.1	157.3	146.3
2nd period diet consumed, lbs.	551.0	551.0	543.5	550.3	543.7	547.3	542.4
Total cottonseed meal consumed, lbs.	80.3	82.1	77.0	77.6	76.8	71.2	70.5
1st period diet, per cwt. gain, lbs.	314.0	381.0	295.0	426.0[1]	353.0	391.0	367.0
2nd period diet, per cwt. gain, lbs.	397.0	397.0	386.0	394.0	393.0	389.0	387.0
Soybean oil ingested, lbs.	14.6	23.2	—	30.4	24.1	27.8	26.9
Corn oil ingested, lbs.	22.4	21.0	26.6	20.7	19.9	21.5	21.1
Cottonseed oil ingested, lbs.	3.7	3.6	2.8	3.5	3.4	3.2	3.2
Starch ingested, lbs.	261.5	245.6	295.3	243.0	243.0	241.8	241.2
Starch to oil[2] ratio (x:1)	7.1	5.5	11.1	4.8	5.5	4.9	5.0

[1] Year 1937–38 not included.
[2] Cottonseed oil not included.

or retarded rate of growth when compared with the expected daily gain of 0.90 pound (Ellis *et al.*, 1939; Hughes *et al.*, 1944). The subnormal gain of 0.67 pound for Group C was caused by limiting the feed intake so that the gain approximated that of the "hogging off" group (D). The highest average daily gain attained was 0.79 pound for group A, whose soybean diet included 20 percent corn. The retarded gains in weight of 0.58 and 0.52 pound for groups E and G are significantly lower than the retarded daily gains of 0.75 and 0.67 pound for the "hogging off" groups (D and F). It has been observed repeatedly that pigs "hogging off" soybeans make better gains in weight than the dry-lot-fed groups.

The average daily gains for the six groups of pigs fed soybeans varied from 0.52 to 0.79 pound per day (table 3). These daily gains of a considerable number of pigs, 240, obtained over a period of five years, are markedly low when compared with the expected daily gain of 0.90 pound for growing pigs in good swine husbandry practice. This retardation of growth is attributed to the heavy feeding of soybeans *per se*.

On the corn hardening diet, the number of pounds of feed required per hundred pounds of gain in weight was quite uniform. Where soybeans were fed the feed required per hundredweight gain varied considerably. The requirement of feed was higher (table 4) than where corn was fed to group C or to group A, where 20 percent corn was included in the soybean diet. These results in carefully controlled dry-lot feeding of both individuals and groups indicate that there are nutritional factors other than calcium and phosphorus lacking in raw soybeans. This deficiency may be cystine[3] (Hayward and Hafner, 1941), or it may be an inhibitory substance acting on proteolysis. Ham and Sandstedt (1944) have reported such an inhibitory substance and state that it retarded growth in chicks. It is destroyed by heat. The observation of the existence of such a substance in soybeans and navy beans has been confirmed by Bowman (1944) where tryptic digestion of casein was retarded. Kunitz (1945) has recently isolated a protein from soybeans which inhibits tryptic digestion.

Firmness of Carcass. The carcasses from groups D and F, based on the fat constants and as judged (tables 5 and 6) were firmer than those of the similarly fed dry-lot groups (E and G), being 1.29 and 1.16 compared to 1.52 and 1.50, respectively (table 5). The former two groups made more rapid gains on soybeans (table 3) as well for the entire experimental period, than did the dry-lot-fed groups (E and G), which made good gains on the hardening diet only.

Group C, which received a diet of corn and protein supplement, had firmer carcasses, as shown by the fat constants, than any of the other groups. By restricting the feed intake during the first period, Group C made essentially the same daily gains for the two periods of feeding as did groups D and F, "hogging off" soybeans. Firmer carcasses for group C are due to certain factors in the feed, such as the absence of the softening unsaturated soybean oil present in soybeans. Greater firmness is caused by the larger intake of the chief hardening agents, starch and cottonseed meal in the corn diet.

According to the fat constants (table 5) the carcasses of both groups of pigs, A and B, that were fed soybeans individually, also graded firm. Even though the diet of group B contained 20 percent more soybeans than the diet for group A, this group graded slightly firmer than group A but was not as firm as the corn fed group (C).

The intake per pig of the chief softening and hardening agents, oil and starch are given in table 4. The ratio of intake of starch to oil varies from 4.8 to 7.1:1 for the groups fed soybeans compared to a ratio of 11.1 for group C

[3] Unpublished data with the white rat using the same variety of soybeans.

fed a supplemented corn diet. Soybeans constituted more than one-half of the diet for group A and over three-fourths of the diet for Group B; still the carcasses of these groups were almost as firm as those of Group C. The firmness of carcass was anticipated because of the hardening effect of the cottonseed meal which was included in the hardening diet (Hostetler *et al.*, 1939).

The total amount of soybeans consumed per pig and consequently the soybean oil ingested is considerable, the latter varying from 14.6 to 30.4

TABLE 5. AVERAGE FAT CONSTANTS AND JUDGES' GRADES OF FIRMNESS FOR SEVEN GROUPS OF PIGS FED IN FIVE SEPARATE TRIALS

Groups	No. of pigs	Refractive index		Iodine number		Melting point		Judges' grade Nos.[1]				Calculated grade from:	
		Back	Leaf	Back	Leaf	Back	Leaf	H	MH	MS	S	Judges[2]	Fat constants
Group D "hogged off" soybeans with protein supplement and mineral mixture, checked by group E dry lot, hand-fed													
D	45	1.4596	1.4590	60.8	56.8	44.5	47.3	32	8	5	—	1.69	1.29±0.17
E	50	1.4598	1.4590	62.4	58.3	44.1	47.0	29	17	4	—	1.92	1.52±0.16
Group F "hogged off" soybeans with mineral mixture self-fed checked by group G dry lot, hand-fed													
F	50	1.4594	1.4590	60.6	57.2	44.7	47.2	41	7	2	—	1.40	1.16±0.16
G	40[3]	1.4597	1.4591	62.7	58.4	44.3	46.9	27	7	6	—	1.80	1.50±0.18
Control group C hand-fed in dry lot, corn diet, restricted to equal the gain of group F													
C	49	1.4592	1.4585	58.7	52.6	44.5	47.4	38	8	2	1	1.55	1.02±0.16
Groups A and B individually fed 38.5 and 78.5 percent soybeans in supplemented diets													
A	25	1.4595	1.4588	60.7	54.7	44.8	47.9	23	1	1	—	1.36	1.18±0.23
B	24[4]	1.4594	1.4587	60.7	55.2	44.9	47.6	21	0	3	—	1.38	1.14±0.23

[1] H=Hard, MH=Medium Hard, MS=Medium Soft, S=Soft.

[2] The following values were assigned for grades of firmness: Hard (H)=1; medium hard (MH)=3; medium soft (MS)=4; soft (S)=6. Hostetler, Halverson and Sherwood, 1939, page 19.

[3] Data from 10 pigs for the first year not included.

[4] Pig No. 8 (1937–38) died en route to Beltsville, Md., for slaughter.

pounds per pig (table 4). Even though the amount of soybean oil consumed per pig was rather high, yet the carcasses from these soybean-fed pigs compared favorably in firmness with those from the corn-fed group (C). If values (Hostetler *et al.*, 1939) of 1 and 3 are used to designate hard and medium-hard grades, respectively, the average values (table 5) vary from 1.02 (group C) to 1.52 (group E) which is between hard and medium hard. When the carcasses are grouped into only two classes, hard and soft as they are on the commercial markets, all groups except E and G would grade 100

per cent firm (table 6) and these two dry-lot-fed groups would grade 97.8 percent firm, according to the grades computed from the fat constants (Hostetler *et al.*, 1939). Although the judges' grades (table 6) were somewhat lower they are in good agreement with the calculated grades.

For practical purposes, 234 pigs fed soybeans in various combinations produced 91.0 percent firm carcasses by the judges' grades and 99.2 percent as shown by the fat constants. The carcasses graded hard, having a mean value of 1.32 ± 0.15, based upon the fat constants of the back and leaf fats (Hostetler *et al.*, 1939) this is confirmed by the judges' data (table 5).

TABLE 6. FIRMNESS OF CARCASSES, EXPRESSED IN PERCENTAGE, FOR SEVEN GROUPS OF PIGS IN FIVE SEPARATE TRIALS

Groups	No. of pigs	Firmness based on fat constants					Firmness based on judges' grades					
		Class[1]		Grades[2]			Class[1]		Grades[2]			
		Firm	Soft	Hard	Med. hard	Med. soft	Firm	Soft	Hard	Med. hard	Med. soft	Soft
D, F	95	100.0	—	85.3	14.7	—	92.6	7.4	76.8	15.8	7.4	—
E, G	90	97.8	2.2	72.2	25.6	2.2	88.9	11.1	62.2	26.7	11.1	—
C	49	100.0	—	89.8	10.2	—	93.9	6.1	77.6	16.3	4.1	2.0
A, B	49	100.0	—	87.8	12.2	—	91.8	8.2	89.8	2.0	8.2	—

[1] As graded commercially.
[2] As graded by judging committee.

The over-all picture shows that the weighted average fat constants for the various groups for five years' feeding are consistent and in close agreement (table 5). The data in table 6 show that almost all of the carcasses in the various groups are firm and that the differences in degree of firmness are small.

The firmness of a total of 283 (49 pigs were not fed soybeans) carcasses when calculated from the fat constants of the back and leaf fats shows that the carcasses are 99.3 percent firm compared to the judges' grade of 91.5 percent which is considered good agreement.

Summary and Conclusions

1. Pigs "hogging off" soybeans (Tokyo variety) made more rapid gains in weight than pigs hand-fed soybeans in dry lot. Both groups, "hogging off" and dry-lot fed, which received both protein supplement and mineral mixture (which supplied calcium, phosphorus and common salt), made a greater average daily gain than the groups similarly fed without the additional protein supplement. The dry-lot group (E) fed a protein supplement made significantly greater gain than group G fed mineral mixture alone.

Of the groups fed individually, the one receiving 20 percent corn and 58.5

percent soybeans in a supplemented ration made a greater average daily gain in weight to 85 pounds than the group fed 78.5 percent soybeans without corn in the diet. Upon reaching the weight of 85 pounds, all pigs were fed the hardening diet of corn, fish meal and cottonseed meal to a marketable weight of 225 pounds with resulting good daily gains in weight.

2. All groups fed soybeans, comprising 234 pigs fed over a period of five years, made subnormal or retarded growth as long as they were fed raw soybeans. This was greatest for the hand-fed dry lot groups (E and G) and the one group (B) fed individually on concrete floors receiving 78.5 percent soybeans, without corn in the supplemented diet.

3. Based on the judges' grade, 91.0 percent of the carcasses from the pigs that had been fed soybeans, were hard. On this same basis only 93.9 percent of the carcasses from the corn-fed group were hard.

The cottonseed meal fed during the hardening period was undoubtedly responsible for the fact that the carcasses from the soybean-fed pigs so nearly approached those from the corn fed pigs in firmness.

4. Pigs can be fed a diet of soybeans alone plus mineral mixture, self-fed, (groups F and G) and yet produce firm carcasses at a marketable weight of 225 pounds, if they are fed the soybeans up to the time they attain an average weight of 85 pounds and are then changed to a diet containing 13 percent of cottonseed meal.

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RELATIONSHIP OF CORN DIETS TO NICOTINIC ACID DEFICIENCY IN GROWING PIGS

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IN A previous paper experiments were reported (Powick, Ellis, Madsen and Dale, 1947) which showed: (1) that most young pigs receiving a purified diet containing 25 percent of casein needed nicotinic acid for growth and well being; (2) that lack of nicotinic acid in most cases resulted in impairment of appetite accompanied by diarrhea and a high incidence of necrotic lesions in the large intestine; and (3) that while pigs seemed to vary in their requirement for nicotinic acid—some pigs requiring none—the amount needed for optimal mean growth seemed to lie between 0.6 and 1.0 mg. per kilogram live weight per day and probably closer to the smaller figure.

Of principal concern is the possible nicotinic acid deficiency under conditions of practical feeding. On the basis of the reported nicotinic acid content of natural feeds (Ellis and Madsen, 1943), it seemed that an otherwise acceptable practical diet might be expected to supply at least 0.6 mg. of nicotinic acid per kilogram live weight per day. Yet various workers (Birch *et al.*, 1937; Chick *et al.*, 1938*a*, 1938*b*; Madison, Miller and Keith, 1939; Davis, Freeman and Madsen, 1940) had reported apparent nicotinic acid deficiency in pigs receiving a diet rich in corn, and it seemed important to put the question to experimental test. This paper reports three feeding experiments with young pigs in which diets consisting largely or principally of ground yellow corn were tested as to their nicotinic acid sufficiency.

Experimental

Experiment 1

In the first of these experiments a basal diet composed of 84 percent ground yellow corn, 15 percent digester tankage, and 0.5 percent each of ground limestone and common salt, supplemented with cod liver oil, was employed. The diet was fed at a 4 to 5 percent level and supplied not less than 0.7 mg. of nicotinic acid per kilogram live weight per day as determined by the chemical method. Four groups of six pigs each, balanced as to total weight and litters of origin, were used. Beginning at an initial age of 57 to 60 days, and continuing for a period of 11 weeks, two groups (A and B) received the basal diet without further addition, while the other two groups (C and D) received the same diet plus nicotinic acid at the rate of 5 mg. per kilogram live weight per day. At the end of 7 weeks of feeding, groups B and D were exposed to infection with S. choleraesuis while groups A and C

were kept as controls. At the end of 11 weeks all pigs were subjected to post mortem examination.

Throughout this experiment the appetite of all uninfected pigs remained normal, diarrhea was negligible and growth, though not optimal, was satisfactory. Infected and uninfected pigs alike were found to be free of necrotic intestinal lesions at autopsy. In short, the basal diet appeared to be equally adequate with or without added nicotinic acid.

Experiment 2

In a second experiment two basal diets were employed. Diet A contained 80 percent ground yellow corn, 2.75 percent digester tankage, 2.75 percent linseed meal, 4.5 percent alfalfa leaf meal, 9.0 percent crude casein and 1 percent mineral mixture. Diet B was similar to diet A, except that it contained 28 percent ground whole oats and 52 percent polished rice instead of 80 percent corn. These diets contained 18.5 and 19.5 percent respectively of protein, and enough nicotinic acid as determined by chemical assay to supply 0.82 and 0.64 mg. respectively per kilogram live weight per day. Supplements of cod liver oil, riboflavin and pantothenic acid were employed with and considered as part of the basal diets.

Three groups of six pigs each, from 41 to 48 days of age, and matched as to litters of origin and total group weight, received respectively: Diet A without further additions, diet A plus 5 mg. of nicotinic acid per kilogram live weight per day, and diet B without further additions.

Through 11 weeks of feeding, the performance of the three groups was good and substantially equal, except for a slight tendency to scour in the group receiving diet B. No deficiency symptoms developed at any time. No effects due to nicotinic acid could be observed. The basal diets appeared to be adequate as to nicotinic acid, nor was any improvement obtained when oats and rice were substituted for corn.

Experiment 3

The third experiment was designed to trace the effect of adding different amounts of corn to the purified diet with which nicotinic acid deficiency had been regularly produced. For this purpose, diets of uniform proximate composition were prepared as shown in table 1. These diets also included supplements of thiamine, pyridoxin, riboflavin, calcium pantothenate, choline, cod liver oil and alpha tocopherol fed in amounts known to be adequate.

In this experiment six litters of four pigs each were employed, one pig from each litter being placed in each of four groups in such manner as to make the groups as uniform as possible in total initial weight. The litters

TABLE 1. COMPOSITION OF DIETS USED IN EXPERIMENT 3

Ingredients	Diet A	Diet B	Diet C
	percent	*percent*	*percent*
Corn,	0.00	40.00	70.00
Purified casein,	25.00	20.72	17.51
Dextrin,	59.50	26.90	2.45
Agar,	2.00	1.14	0.46
Lard,	10.00	8.28	6.99
Salt mixture,	3.50	2.98	2.59
Protein, by analysis,	22.35	22.24	22.57
Nicotinic acid, mg./kg./d.,	0.08	0.36	0.47

varied in age from 37 to 44 days. Three groups received diets A, B, and C respectively, while the fourth group received diet C plus 5 mg. nicotinic acid per kilogram live weight per day. Each group was fed collectively and so far as possible at a 4 percent level: but whenever the consumption of feed fell below this amount, the full amount of accessory supplements was added to a reduced amount of feed. The individual pigs were weighed at weekly intervals and the cumulative gain in weight for each pig was expressed as percentage of its initial weight. Daily observations, applicable to groups rather than to individuals, were made for signs of diarrhea or of impaired appetite.

At the end of six weeks of feeding, striking and highly significant differences in the effects of the several diets were evident. The experiment was therefore terminated and the surviving pigs were subjected to post mortem examination. The results are listed in table 2.

In respect to gain in weight, group 4 surpassed groups 2 and 3 by margins of high statistical significance, and group 1 by a margin of ordinary signifi-

TABLE 2. FEEDING RESULTS ON PIGS IN EXPERIMENT 3

Item	Group No.			
	1	2	3	4
Corn in diet, percent,	0.00	40.00	70.00	70.00
Nicotinic acid in diet, mg./kilo/d.	0.08	0.36	0.47	5.47
Mean gain as percent of initial weight,	60.30	13.30	49.70	134.30
Impaired appetite, percent of total days,	54.90	84.80	66.70	11.40
Diarrhea observed, percent of total days,	91.00	82.50	66.90	5.10
Mortality, No. of pigs,	2	2	0	0
Necrotic lesions, No. of pigs,	4	5	3	0

cance. Group 3 surpassed group 2 by a significant margin, while group 1 surpassed group 2 by a highly significant amount. Taking group 4 as the standard of reference, group 2 with 40 percent corn showed a highly significant lag in growth by the end of the third week, group 3 with 70 percent corn showed a significant lag by the end of the fourth week, and group 1 a significant lag by the end of the fifth week.

Statistical analysis of the observations on appetite and on incidence of diarrhea is not possible since no estimate of error is available, but the superiority of group 4 seems convincing. Nor is the number of deaths occurring in groups 1 and 2 sufficient to demonstrate significant difference between these and the other groups in respect to mortality. In respect to the incidence of necrotic lesions of the large intestine, however, the probability of chance being responsible for the differences between group 4 on one hand and groups 1, 2 and 3 on the other, is but 1:33, 1:132, and 1:11 respectively.

There is no doubt that pronounced nicotinic acid deficiency was produced by the feeding of diets A, B and C and was prevented by the addition of nicotinic acid to diet C. It further appears that the addition of 40 percent corn to the purified diet accentuated the deficiency symptoms produced by the purified diet alone, and this in spite of the nicotinic acid supplied by the corn itself. There is the further suggestion, for which a valid explanation is not apparent, that the diet containing 70 percent of corn was less detrimental to the pigs receiving it than was the diet containing 40 percent of corn.

Discussion

In the three experiments here reported, nicotinic acid deficiency was produced by diets supplying 0.08, 0.36 and 0.47 mg. of nicotinic acid per kilogram live weight per day. It was not produced by diets supplying 0.64, 0.7 or 0.82 mg. per kilogram live weight per day. This is consistent with our previous estimate of 0.6 to 1.0 mg. per kilogram live weight per day as the probable requirement for groups of growing pigs receiving a purified diet. One gains the impression that the nicotinic acid requirement was increased little if any by the feeding of high percentages of corn in diets otherwise made up of purified constituents.

Yet in the third experiment, 40 percent of corn added to a purified diet appeared to exert a very definite pellagragenic effect, as measured by the severity of symptoms. The fact that these symptoms were ameliorated when 30 percent more corn with its nicotinic acid contribution, was added to the diet suggests that in case of pigs, at least, this pellagragenic effect may not be an anti-nicotinic effect but merely an aggravation of symptoms that occurs only in the absence of adequate nicotinic acid.

Doubtless nicotinic acid deficiency can be produced by diets composed of common feeds. At least the English workers (Birch *et al.*, 1937; Chick *et al.*, 1938*a*, 1938*b*; Braude *et al.*, 1946) appear to be able to produce deficiency symptoms with considerable regularity with a diet containing 77.5 percent maize meal, 10.5 percent pea meal, and 6.5 percent purified casein, and assaying 15.3 percent protein; while other workers have obtained similar deficiencies on diets consisting largely of corn, but not otherwise specifically described. In most of these cases it would seem that the diets were lower in protein than would obtain in good practice, while in some instances the distinction between dietary deficiency and possible salmonella infection is not sufficiently clear. Wintrobe *et al.* (1945) in particular believe that restriction of protein in the diet increases the likelihood of nicotinic acid deficiency. Burkholder *et al.* (1944) also report a wide variation in the nicotinic acid content of various strains of corn, which suggests the possibility that corn of lower nicotinic acid content than ours may have been responsible for some of the reports of nicotinic acid deficiency in pigs receiving diets high in corn.

Summary

1. Two experiments are reported in which no evidence of nicotinic acid deficiency could be noted in growing pigs receiving diets containing 80 and 84 percent of corn respectively and supplying at least 0.7 and 0.8 mg. of nicotinic acid respectively per kilogram live weight per day.

2. A third experiment is reported in which severe nicotinic acid deficiency resulted from feeding diets containing 40 and 70 percent of corn combined with purified materials, and supplying 0.36 and 0.47 mg. of nicotinic acid respectively per kilogram live weight per day.

3. Evidence of a pellagragenic effect of corn was obtained which appeared to be not necessarily an anti-nicotinic acid effect.

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THE VALUE OF SUNFLOWER-SEED MEAL IN RATIONS FOR GROWING-FATTENING PIGS[1]

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Introduction

IN AN experiment at the Missouri Agricultural Experiment Station, sunflower seed was compared with tankage as a protein supplement for fattening hogs in drylot weighing over 100 pounds initially (Weaver, 1921). A ration composed of equal parts of sunflower seed and corn compared favorably with a ration containing 10 parts corn and one part tankage. Both groups received minerals free-choice. The results of pig feeding tests reported by the Rowett Research Institute in Scotland indicated that sunflower-seed cake (Russian) can replace two-thirds of the fish meal in a growing ration (15 percent crude protein) consisting chiefly of cereals and cereal by-products. In other tests, the results showed that sunflower-seed cake had the same feeding value as soybean meal and peanut meal. Mitchell, Hamilton, Beadles and Simpson (1945) published results of feeding sunflower-seed meal to Albino Rats. They reported that the protein of sunflower-seed meal was 94.3 percent digestible and possessed a biological value of 64.5. The decorticated sunflower-seed meal used by Mitchell *et al.* was defatted by a solvent extraction method involving low temperatures throughout (less than 75° C.). Similarly prepared sunflower-seed meal was fed in the tests reported in this paper. It was prepared by the VioBin Corporation of Monticello, Illinois, and was donated to the Illinois Agricultural Experiment Station by the VioBin Corporation and the Piatt County (Illinois) Sunflower Committee. The composition, including the vitamin content, of sunflower-seed meal has been reported in Illinois Agricultural Experiment Station Circular 608 (1947).

The tests were designed: (1) to compare sunflower-seed meal with meat scraps as a source of supplemental protein for young pigs fed in drylot; and (2) to determine its value in replacing both meat scraps and soybean meal in supplemental mixtures fed under drylot conditions. Both paired-feeding and group-feeding techniques were used.

[1] The decorticated sunflower-seed meal used in these tests was kindly prepared by the VioBin Corporation of Monticello, Illinois, and donated to the Agricultural Experiment Station by the Corporation and the Piatt County (Illinois) Sunflower Committee. It was prepared by a low-temperature solvent-extraction process, after the hulls were mechanically removed.

[2] Acknowledgment is gratefully made for the assistance of R. F. Van Poucke, formerly Assistant in Swine Husbandry, and R. H. McDade, Chief Swine Herdsman, and his associates.

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Methods

Paired-feeding

In this part of the study two rations were compared, in one of which meat scraps was the source of supplemental protein, in the other, sunflower-seed meal. Nine pairs of purebred Duroc-Jersey pigs were fed for equal gains. The pigs averaged about 45 pounds initially and were fed to an average final weight of 97 pounds. One pig of each pair received the meat scraps ration while the other pig was fed the ration which contained sunflower-seed meal. The pigs were fed and managed according to the method described by Krider, Fairbanks and Carroll (1944). The rations fed are given in table 1. A suboptimum level of 14 percent crude protein in the rations was fed to test more critically the value of the protein supplements.

TABLE 1. RATIONS FED THE GROWING PIGS IN THE PAIRED-FEEDING TEST

Feed	Meat scraps ration	Sunflower-seed meal ration
	Percent	*Percent*
Ground yellow corn	84.0	79.0
Alfalfa leaf meal (dehydrated)	5.0	5.0
Meat scraps	10.0	—
Sunflower-seed meal	—	12.5
Steamed bone meal	—	2.5
Iodized salt	0.5	0.5
Fortified vitamin A and D oil[2]	0.5	0.5
Total	100.0[1]	100.0[1]

[1] Manganese sulfate added at the rate of ½ pound per 1000 pounds of ration.
[2] Guaranteed to contain 2000 I.U. of vitamin A and 400 U.S.P. units of vitamin D per gram

The chemical composition of the meat scraps (dry-rendered), sunflower-seed meal, and dehydrated alfalfa leaf meal used in the paired-feeding experiment is given in table 2.

Group-feeding

Three lots of twenty Duroc-Jersey pigs each were fed in drylot. The pigs had been on pasture previously and averaged about 50 pounds initially. In lot 1 the pigs were fed to an average final weight of approximately 186 pounds, and the pigs in lot 3 were weighed off test when pigs in lot 2 reached a final average weight of 183 pounds. All groups were fed shelled yellow corn, a simple mineral mixture (40% ground limestone, 40% steamed bone meal, and 20% iodized salt) and a protein-vitamin supplement, free-

TABLE 2. PERCENTAGE COMPOSITION OF THE MEAT SCRAPS, SUNFLOWER-SEED MEAL AND ALFALFA LEAF MEAL (FRESH BASIS)

	Dry substance	Crude protein	Ether extract	Ash	Crude fiber	Nitrogen free extract
Meat scraps, dry-rendered	93.40	54.21	11.58	20.16	2.97	4.48
Sunflower-seed meal	93.13	46.19	5.30	5.28	6.71	29.65
Alfalfa leaf meal (dehydrated)	93.72	21.62	2.04	8.39	27.39	34.28

choice. The supplements fed to the various lots were composed of the following feeds in the proportions indicated:

	Lot 1 *Pounds*	*Lot 2* *Pounds*	*Lot 3* *Pounds*
Alfalfa meal, sun-cured	100	100	100
Meat scraps, dry-rendered	100	—	—
Soybean meal, expeller	100	100	—
Sunflower-seed meal	—	100	200
Total	300	300	300

The meat scraps and the sunflower-seed meal fed contained 54.7 percent and 56.1 percent crude protein, respectively. The sun-cured alfalfa meal was of good quality and contained 16.6 percent crude protein. The soybean meal and the shelled yellow corn contained 45.0 percent and 8.4 percent crude protein, respectively.

Results

Paired-feeding

The results of the drylot paired-feeding test are summarized in table 3. In six of the nine pairs the pig fed meat scraps required less feed per pound of gain, while in three pairs the test pig required more feed. A statistical analysis of the data by Student's method with argument "t" as described by Snedecor (1940) for paired differences show that the results on economy of gain are too nearly a chance distribution to indicate any significant differences in the feeding value of the two rations.

A record of feed refusals indicated that the feed mixture containing sunflower-seed meal was consumed more readily than the one containing meat scraps. During the experiment a part of the ration was refused by the pigs fed meat scraps at 81 feedings and there were only 17 refusals by pigs fed

sunflower-seed meal. This deviation from the ideal of a chance distribution was highly significant.

In this comparison, 100 pounds of sunflower-seed meal were equal to

TABLE 3. RESULTS OF PAIRED-FEEDING FOR EQUAL GAINS (1945 SUMMER)[1]

Pair No.	Lot No.	Initial weight	Final weight	Days on test	Average daily gain	Daily feed consumed	Feed consumed per 100 pounds gain
1	A[2]	65	100	77	0.45	1.73	381
	B[3]	62	99	77	0.48	1.89	393
2	A	54	109	105	0.52	1.97	376
	B	49	104	105	0.52	1.81	345
3	A	48	105	98	0.58	1.88	324
	B	53	105	98	0.53	1.95	368
4	A	43	95	91	0.57	1.88	328
	B	46	100	91	0.59	2.15	362
5	A	41	97	91	0.62	2.00	326
	B	45	99	91	0.59	2.08	351
6	A	43	93	133	0.38	1.55	413
	B	40	93	133	0.40	1.44	362
7	A	41	107	112	0.59	1.84	312
	B	39	102	112	0.56	1.94	344
8	A	36	100	126	0.51	1.68	331
	B	35	96	126	0.48	1.69	349
9	A	31	71	140	0.29	1.15	401
	B	32	75	140	0.31	1.21	395
Av.	A	44.7	97.4	108.1	0.50	1.74	355
Av.	B	44.6	97.0	108.1	0.50	1.80	363

[1] All weights in pounds.
[2] A = Meat scraps (54.2% protein) fed as supplement.
[3] B = Sunflower-seed meal (46.2% protein) fed as supplement.

78.2 pounds of meat scraps plus 24.9 pounds of ground yellow corn minus 20 pounds of steamed bone meal and 0.7 pound of alfalfa leaf meal in producing 100 pounds of gain,

At the close of the paired-feeding trial, the pigs receiving both rations appeared to have smooth normal colored hair coats, clean skins, and normal feet, legs and gaits.

Group-feeding

In table 5, the results of the group-feeding experiment are reported.

A statistical analysis of the average daily gains showed that lots 1 and 2 did not differ significantly, but the difference in average daily gains between

TABLE 5. RESULTS OF FEEDING SUNFLOWER-SEED MEAL AS A PROTEIN SUPPLEMENT FOR PIGS IN DRYLOT, (1946 SUMMER). ALL LOTS WERE SELF-FED SHELLED YELLOW CORN, MINERALS[1] AND SUPPLEMENT, FREE-CHOICE

Items compared	Lot number and supplement fed		
	1	2	3
	1 meat scraps 1 soybean meal 1 alfalfa meal	1 soybean meal 1 alfalfa meal 1 sunflower-seed meal	1 alfalfa meal 2 sunflower-seed meal
No. of pigs	20[2]	20	20[2]
Days on test	92	102	102
Av. initial wt., lbs.	51.1	50.5	50.2
Av. final wt., lbs.	185.7	183.3	162.1
Av. daily gain, lbs.	1.46±.066	1.30±.054	1.10±.068
Av. daily feed			
Shelled yellow corn, lbs.	4.25	3.85	3.32
Supplement, lbs.	1.06	.86	.82
Minerals, lbs.	.13	.17	.19
Total, lbs.	5.44	4.88	4.33
Feed eaten per 100 lbs. gain:			
Shelled yellow corn, lbs.	289.6	296.6	302.6
Supplement, lbs.	72.6	66.3	76.0
Minerals, lbs.	9.2	13.2	17.0
Total, lbs.	371.4	376.1	395.6
Coefficient of variation of av. daily gains	19.2	18.1	26.4

[1] Minerals: 40% steamed bone meal, 40% limestone, 20% iodized salt.
[2] One pig was removed.

lots 1 and 3 was highly significant.[4] The average daily gains of the pig in lot 2 were significantly[5] more rapid than those obtained in lot 3. The gains of the pigs in lot 3 were not as uniform as the gains of the pigs in lots 1 and 2 as indicated by the coefficients of variation.

[4] $P \leq .01$.
[5] $P \leq .05$.

The results from lots 1 and 2 show that each 100 pounds of sunflower-seed meal were equal to 109.5 pounds of meat scraps plus 9.5 pounds of soybean meal plus 9.5 pounds of alfalfa meal minus 31.7 pounds of shelled corn and 18.1 pounds of minerals in producing 100 pounds of gain.

After the pigs had been on test for about 80 days, it was apparent that the pigs receiving the supplement containing meat scraps were not only gaining more rapidly than those in the other two lots but were also showing normal hair coats while those in lot 3 were showing marked depigmentation of the hair. At the close of the test, every pig in lot 1 showed a normal red haircoat, while 55 percent of those in lot 2 showed depigmentation, and 80 percent of those in lot 3 showed this condition.

The depigmentation was characterized by a lack of the red color in the hair that was grown by the pigs while on the experimental rations. In the most affected pigs, the tips of the hairs were bright red in color indicating that the haircoat color was normal when the pigs were started on test. The newly grown portion of the hair was almost devoid of pigment and such pigs appeared to be much lighter in color.

After being on feed for 102 days, the pigs in lots 2 and 3 were weighed-off and the group-feeding test closed so that some observations could be made on the nature of the deficiency of the ration fed to lot 3. During the last two weeks on test, the pigs in lot 3 were consuming the various feeds in the following proportions: yellow corn 78 percent, alfalfa meal 6.7 percent, sunflower-seed meal 13.3 percent, and minerals 2 percent. This is referred to as the basal ration in this observation.

Ten of the pigs showing the most depigmentation from lot 3 were divided into three groups. The complete ration was ground and mixed in the proportions given above and was fed as follows:

Group I. Basal ration (4 pigs).
Group II. Basal ration plus 0.1% lysine (2 pigs).
Group III. Basal ration plus 12 mg. pantothenic acid[6] per pound of ration (4 pigs).

The two pigs showing most depigmentation were placed in group II and were fed 0.1 percent lysine as a supplement. These were also the smallest pigs. The remaining eight pigs were equated between groups I and III. Depigmentation or graying of the pelt of certain foxes has been reported to be due to a pantothenic acid deficiency. It seemed desirable to feed pantothenic acid to learn whether or not this factor was involved in the depigmentation of the pigs' hair, even though the basal ration should have contained an adequate amount of pantothenic acid, and the pigs exhibited normal gaits.

When the pigs were placed on this test an area of hair on the right side of each pig was clipped and the hair was examined closely. After 30 days on

[6] Obtained through the courtesy of Lederle Laboratories, Inc., Pearl River, New York.

the treatments indicated, the newly grown hair from the clipped area was cut and a color comparison was made with the original sample.

Both pigs in group II grew normally colored red hair while being fed the lysine supplement. One pig showed a slight improvement in pigmentation while the other pig showed marked improvement. The pig showing the slight change grew hair slowly and had a thin hair coat while the pig that showed a marked change in hair coat color grew his hair coat rapidly and had a thick hair coat.

The results in groups I and III were negative except that one pig in each group showed very slight improvement in pigmentation of the hair.

While these results are not conclusive, it is indicated that lysine was the limiting amino acid in the ration tested and that lysine is essential for normal pigmentation of the hair of Duroc-Jersey pigs.

This basal ration was also fed to black rats in the Animal Nutrition Laboratory at the University of Illinois and the hair coats of these animals turned gray, indicating that a nutrient essential for normal pigmentation was deficient. Researches of Fritz *et al.* (1946) showed that an abnormal amount of white feather coloring developed in bronze poults raised in confinement and fed diets containing a large percentage of vegetable protein feeds. By adding lysine to the diet, the syndrome was prevented. Growth of the poults varied inversely with the incidence of pigmentation failure which was also true with the pigs in this group-feeding experiment.

The pigmentation failure was not noted in the pigs that were pair-fed, probably because the growth rate was much slower than in the group-feeding test. Fritz *et al.* (1946) indicated that the lysine requirement for optimum growth may be slightly lower than for normal feather color in bronze poults. It may be that the rations fed in the paired-feeding test contained enough lysine to support the relatively slow growth rate and to promote growth of normal colored hair. However, in the group-feeding test where larger amounts of feed were consumed and growth was more rapid, the deficiency became apparent.

Summary and Conclusions

The value of sunflower-seed meal was compared with meat scraps for growing-fattening swine in drylot using the paired-feeding and group-feeding techniques.

In the feeding of nine pairs of young Duroc-Jersey pigs for equal gains, the rations contained 14 percent of crude protein. The protein was derived from yellow corn and alfalfa leaf meal and either 10 percent of meat scraps or 12.5 percent sunflower-seed meal. Each ration contained iodized salt and fortified vitamin A and D oil, and 2.5 percent of steamed bone meal was added to the sunflower-seed meal ration. The feed required for each 100 pounds of gain was 355 pounds and 363 pounds, respectively, in the meat-

scrap ration and the sunflower-seed meal ration. This difference was shown to be well within the experimental error of the feeding method employed.

In the group-feeding test, three lots of twenty Duroc-Jersey pigs, each averaging about 50 pounds per pig initially, were fed in drylot. The rations were self-fed, free-choice, with all lots receiving shelled yellow corn, a mineral mixture and a protein-vitamin supplement. In lot 1, the supplement was composed of equal parts of alfalfa meal, soybean meal and meat scraps; while sunflower-seed meal replaced the meat scraps in the supplement fed to lot 2 and it replaced both soybean meal and meat scraps in the supplement fed to lot 3.

The rate of gain was decreased, but not significantly, when sunflower-seed meal replaced the meat scraps in the supplement. Both supplements proved to be very economical with 371 and 376 pounds of feed being required to produce 100 pounds of gain on the meat-scraps ration and sunflower-seed meal ration, respectively.

When sunflower-seed meal replaced both meat scraps and soybean meal, the rate of gain was significantly decreased and the amount of feed eaten per 100 pounds of gain increased to 396 pounds. After these Duroc-Jersey pigs had been on test for 13 weeks, 80 percent of them were showing depigmentation of the hair, whereas those receiving meat scraps in the supplement had normal hair coats.

Further observations indicated that the supplement containing only sunflower-seed meal and alfalfa meal was deficient in lysine for optimum growth and normal pigmentation of the hair in Duroc-Jersey pigs.

These experiments indicate that sunflower-seed meal can be used most advantageously as a part of the protein-vitamin supplement fed in drylot. Since its inclusion in place of meat scraps and/or soybean meal decreased the rate of gain of pigs fed in drylot, it probably should be used in place of only a part of the soybean meal and/or meat scraps.

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OBSERVATIONS ON THE THIAMINE, RIBOFLAVIN, AND CHOLINE NEEDS OF SOWS FOR REPRODUCTION[1]

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THE nutritional requirements of the sow during gestation and lactation are of great practical importance. Adequacy of the ration fed swine during growth is a very important factor since it definitely affect the results obtained later during reproduction and lactation (Cunha *et al.*, 1944; Cunha, Warwick and Ensminger, 1946). Work by Krider, Fairbanks and Carroll (1944), Fairbanks, Krider and Carroll (1945), and Krider *et al.* (1946) has shown the importance of adequate nutrition during gestation as a factor in promoting successful lactation. Fairbanks, Krider and Carroll (1944, 1945) have shown that, after weaning, pigs from sows fed more nearly adequate rations during lactation manifested a residual effect of the higher nutritional regime. Death losses of young pigs present a serious economic problem, it being estimated by Smith (1937) that only 60 percent of the annual pig crop reaches the market. Investigations in recent years have added greatly to the knowledge of the nutritive requirements of the pig. However, the specific effects of certain B-complex vitamin deficiencies on reproduction and lactation by the sow have not definitely been established. A lack of certain B-complex vitamins, or combinations of them, in the ration of the sow undoubtedly are responsible for a good portion of the small pig losses sustained yearly in this country.

The work reported herein was undertaken in order to determine the effects of a lack of either thiamine, riboflavin, or choline in the ration of sows during reproduction and lactation.

Materials and Methods

To the knowledge of the investigators, no work is reported in the scientific literature on the use of purified rations for sows during gestation and lactation. Accordingly, in a preliminary trial beginning in March 1945, two sows were fed a purified ration supplemented with the six B-complex vitamins (thiamine, riboflavin, niacin, pyridoxine, pantothenic acid, and choline). Later, during the spring and summer of the same year, the project was further enlarged by feeding eight additional sows on the same purified ration

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[2] The assistance of Dean C. Lindley and Wilton W. Heinemann in the 1945 trials and L. K. Bustad in the 1946 trials is acknowledged. Dr. D. R. Cordy, College of Veterinary Medicine, performed the post-mortem and microscopic examinations of the small pigs in the 1946 trials.

during gestation and lactation. However, with two sows in each group, thiamine, riboflavin and choline were deleted from the ration. This study was repeated during the spring and summer of 1946 when eight more sows were used, the rations being the same as in the preceding year. In the latter trial, litter mates were used in each of the four lots, thus lessening the effects of genetic variation.

In the preliminary trial, in which the adequacy of the basal ration was studied, two eight-month-old Chester White gilts were used. These two gilts were bred to the same Danish Landrace boar.[3] In the subsequent and larger study in 1945, in which thiamine, riboflavin and choline were each omitted from the ration of two gilts, eight nine-month-old Chester White gilts were bred to another Danish Landrace boar. In the 1946 study, eight eight-month-old Chester White gilts were bred to still another Landrace boar. In this trial, the boar was left with the gilts for the duration of two heat periods to try to assure conception. A chemical test for diagnosis of pregnancy in swine (Roth *et al.*, 1941) was also run on the gilts.

Prior to being placed on the purified ration, all gilts were fed the regular college herd ration consisting of 20 percent alfalfa meal, 5 percent tankage, plus wheat, barley, cull peas, wheat bran and minerals.

The gilts were kept on raised floors during the 1945 trials in order to guard against coprophagy. Neither the gilts nor their litters showed any tendency toward this practice. During the 1946 trials, raised floors were not used but the concrete floors were carefully washed twice daily. As before, no tendency was shown towards coprophagy. Individual feeding stalls, as described by Ensminger *et al.* (1944), were used, each gilt eating in the same stall at every feeding. This procedure was followed in order to carry out a modification of the "paired-feeding" technique (Mitchell and Beadles, 1930). A similar feeding technique was used successfully with pigs by Ensminger *et al.* (1944). According to this method, the feed consumption of gilts 164 and 166, in the earlier pilot trial, was kept approximately the same. As certain animals in the subsequent trials lost their appetite or became so erratic in their eating habits as to jeopardize the results of the entire group, the paired feeding technique was altered.

The composition of the two different purified rations used is as follows:

	Ration "A"[4]	*Ration "B"*
Casein[5]	26.1%	20.0%
Sucrose	57.7	63.8
Lard	11.0	11.0
Mineral mix	5.2	5.2
	100.0	100.0

[3] This cross was used simply because the animals were available as part of a cross-breeding program underway at this institution at the time this experiment was initiated.

A lower amount of protein was used in ration "B," the choline deficient ration and its control, since higher levels of protein would provide excess methionine from which methyl groups might be derived for the synthesis of choline from its precursor. The allotment of the gilts is shown in table 1. The levels of vitamins fed to the gilts during the three trials are shown in table 2.

TABLE 1. DISTRIBUTION OF GILTS, IN 1945 AND 1946 TRIALS

Lot numbers		Ration	Total No. gilts	Vitamins* fed or deleted
1945	1946			
A (Pilot trial)		"A"	2	Pilot trial—6 B-vitamins** fed
I a	I a	"A"†	2	Controls—6 B-vitamins fed
I b	I b	"B"‡	2	Controls—6 B-vitamins fed
II	II	"A"	4	Thiamine deleted from 6 B-vitamins
III	III	"A"	4	Riboflavin deleted from 6 B-vitamins
IV	IV	"B"	4	Choline deleted from 6 B-vitamins

* Vitamins A, D, E, K, fed in all cases.

** Thiamine, riboflavin, niacin, pyridoxine, pantothenic acid and choline.

† Contains 26.1 percent casein.

‡ Contains 20.0 percent casein.

In 1946, slight increases were made in vitamins A, D, and E. However, the rate of feeding the B-complex group of vitamins remained the same in both of the larger trials during 1945 and 1946.

The levels of the vitamins fed were in excess of the recommended allowances for growing pigs as reported by Hughes *et al.* (1944). The sucrose and lard were of commercial table grade. The crystalline B-complex vitamins were made into 20 percent ethanol solutions and stored in dark amber bottles in a refrigerator. Two days' requirements of all vitamins were added to a small amount of feed on the top of the ration in the trough just before feed-

[4] Purified ration "A" same as used by Wintrobe (1939), except that the mineral mix has been modified as shown by Heinemann et al. (1946)

[5] In the 1945 trials, the casein used was acid washed. Obtained through cooperation of Mr. G. D. Turnbow, Vice President and General Manager, and Dr. Paul F. Sharp, Director of Research, Golden State Co., Ltd., San Francisco, California. In the 1946 trials, Vitamin Test Casein, which was alcohol extracted, was used; obtained through the cooperation of General Biochemicals Inc., Lab. Park, Chagrin Falls, Ohio.

TABLE 2. VITAMIN SUPPLEMENTS FED TO THE EXPERIMENTAL ANIMALS IN THE 1945 AND 1946 TRIALS IDENTICAL LOTS I TO IV IN EACH YEAR, 1945 AND 1946

Vitamin supplement[1]	A (Pilot trial of 1945)		Lot I*	Lot II*	Lot III*	Lot IV*
	During gestation	During lactation				
Thiamine	0.22 mg.	0.25 mg.	0.19 mg.	No thiamine	0.19 mg.	0.19 mg.
Riboflavin	0.27 mg.	0.32 mg.	0.24 mg.	0.24 mg.	No riboflavin	0.24 mg.
Niacin	1.09 mg.	1.25 mg.	0.94 mg.	0.94 mg.	0.94 mg.	0.94 mg.
Pantothenic acid	1.62 mg.	1.86 mg.	1.40 mg.	1.40 mg.	1.40 mg.	1.40 mg.
Pyridoxine	0.27 mg.	0.31 mg.	0.23 mg.	0.23 mg.	0.23 mg.	0.23 mg.
Choline	23.12 mg.	26.66 mg.	20.00 mg.	20.00 mg.	20.00 mg.	No choline

Per sow daily (all lots):

	1945 trials	*Fed as*	*1946 trials*	*Fed as*
Vitamin A	20,000 I.U.	(Shark liver oil)[2]	26,000 I.U.	(Percamorph liver oil)
Vitamin D	1,500 I.U.	(Viosterol)	3,800 I.U.	(Percamorph liver oil)
Vitamin E	150 mg.	(Mixed tocopherols)[3]	155 mg.	(Alpha-tocopherol)[4]
Vitamin K	10 mg.	(Menadione)[3]	10 mg.	(Menadione)[4]
Vitamin C	—	—	150 mg.	(Ascorbic acid)[5]

[1] Amounts are daily per kg. body weight unless otherwise indicated.

[2] Bio-Vita 10 MA. Natural shark liver blend containing 10,000 I.U. vitamin A per g. Kindly supplied by T. R. Carruthers, Bioproducts, Inc., Astoria, Oregon.

[3] Supplied through the courtesy of Dr. T. H. Jukes, Lederle Laboratories, Pearl River, New York.

[4] These vitamins and B-complex vitamins were supplied through the courtesy of Dr. D. F. Green of Merck and Co., Inc., Rahway, N. J.

[5] Fed to only one gilt in each group.

* These vitamin levels were fed during gestation and lactation.

ing time. This method of feeding vitamins made struggling with the animals unnecessary.

In order to protect the ingredients against the development of rancidity, the rations were stored in a refrigerator and only two or three days' feed requirements were mixed and on hand at any one time.

A saturated solution of ferrous sulfate plus traces of copper and cobalt was swabbed daily on the udders of the gilts in order to guard against the development of anemia in the suckling pigs.

At the termination of the experiment, gilts used in 1946 were slaughtered and riboflavin and thiamine analysis were conducted on samples of heart, liver, kidneys, hams, shoulder and loin. Samples (whole pig) of the small pigs which died at birth or immediately after were also analyzed for riboflavin and thiamine. The thiamine and riboflavin analyses were determined according to the method of Conner and Straub (1941) with modifications by Peterson *et al.* (1943) and Bedford *et al.* (1944).

Results and Discussion

A summary of the gestation, farrowing, and lactation record of the individual sows is given in table 3, and summaries of the thiamine and riboflavin analyses of the tissues of the gilts and of the baby pigs in the 1946 trials is contained in tables 4 and 5.

In these trials, only a limited number of animals were used. Thus, the results herein reported should merely be considered as an indication rather than conclusive in nature. Even so, the comparison will be of value to investigators working on the vitamin needs of sows during reproduction and lactation.

The Control Gilts

Unfortunately, the two gilts (No. 434 and 436) fed the control ration in the 1945 trials did not farrow, apparently having failed to conceive. However, gilts 164 and 166, which were used in the earlier pilot trials and which received a similar control or basal ration, did farrow and weaned satisfactory litters when fed for a short period of time during gestation. Again, in the 1946 trials, difficulty was encountered in getting the control gilts to conceive. Only one control gilt, No. 576, farrowed a litter of pigs. It is difficult to say whether this failure in getting gilts to conceive is due to chance or to something about the ration. Gilt 576 conceived after having missed two heat periods. Her litter appeared normal but only one pig out of ten survived more than 24 hours. It should be emphasized that gilts 164 and 166 were placed on the purified ration only 52 days prior to farrowing, whereas the balance of the animals in 1945 were started on similar rations an average of 75 days before parturition while the control gilt which farrowed in 1946 was on the purified ration for 140 days prior to parturition. These results might indicate the need for some unknown factor(s) or probably some other known B-complex vitamin (biotin, inositol, para-aminobenzoic acid, and folic acid) not included in the ration. Data of Cunha, Lindley and Ensminger (1946), Lindley and Cunha (1946), and Cunha *et al.* (1946) have shown that the addition of biotin, folic acid, para-aminobenzoic acid and inositol does not help growth or efficiency of feed utilization in the young pig fed a purified ration. However, that does not eliminate the possibility that these vitamins may be needed for reproduction and lactation. The possibility of an unknown factor or factors being required is made since Cunha *et al.* (1944), Ross *et al.* (1944), and Krider *et al.* (1946*b*) showed such a need by sows fed natural rations during reproduction and lactation.

A total of six gilts were used as controls during the two years, receiving the purified ration supplemented with the six B-complex vitamins (thiamine, riboflavin, niacin, pyridoxine, pantothenic acid, and choline). Satisfactory

TABLE 3. GESTATION AND LITTER RECORD

Type of ration	Sow No.	No. of days on ration before parturition	Length of gestation period, days	No. pigs farrowed	No. pigs born dead	Av. birth wt., lbs.	Weaning days, age	No. pigs weaned	Av. weaning wt., lbs.	Initial wt. of gilts, lbs.	Av. daily gains to farrowing, lbs.	Av. daily feed consumption during gestation lbs.	Total weight gain or loss in lactation, lbs.	Av. daily feed consumption during lactation, lbs.
1945 Trials														
Control	164	52	114	10	0	2.44	42	8	20.6	368	1.19	5.55	−66	5.29
Control	165	52	112	8	0	2.70	42	6	21.46	324	1.50	4.32	−65	5.19
Control	434	Didn't farrow								225		3.95		
Control	436	Didn't farrow								210		3.29		
B_1 deficient	359	71	103	7	0	2.61	56	5	19.6	272	0.57	2.26	+21	4.63
B_1 deficient	403	74	105	9	0	1.98	56	7	19.46	238	0.74	2.22	−13	4.77
Riboflavin deficient	338	68	98	10	6	1.96	—	0	—	260	0.13	1.96		
Riboflavin deficient	357	71	110	8	5	1.96	—	0	—	267	0.04	2.00		
Choline deficient	351	81	116	7	0	2.34	56	2	22.00	297	0.95	3.25		
Choline deficient	402	84	114	11	0	2.38	56	9	17.28	229	1.08	3.24		
1946 Trials														
Control	554	Didn't farrow								307		4.15*		
Control	576	140	114	10	7	2.40	12	1**		285	.99	3.87	+6	4.27
Thiamine deficient	552	Didn't farrow								294		3.83*		
Thiamine deficient	571	96	118	8	3	2.80	—	0	—	312	1.21	3.67		
Riboflavin deficient	551	85	105	12	12	1.65	—	0	—	269	.82	3.51		
Riboflavin deficient	569			11*	11*	.83	—	0	—	315	.45	3.39		
Choline deficient	567	88	115	3	0	2.56	42	1	21.5	287	.83	3.79	−1	4.33
Choline deficient	574	91	114	11	1	2.40	42	1	21.0	310	.88	3.81	−27	4.66

* Removed from the uterus when sow was slaughtered 2 weeks after normal date of farrowing.
* Based on 90 day feed consumption.
** Weaned at this age to conserve feed.

TABLE 4. AVERAGE THIAMINE* AND RIBOFLAVIN* ANALYSES OF GILTS USED IN 1946 TRIALS

Lot	No. animals	Heart	Liver	Kidney	Composite av. of internal organs	Shoulder	Loin	Ham
				Thiamine				
Control	2	4.56	2.73	3.08	3.46	—	—	7.83
Thiamine-deficient	2	1.19	0.58	0.83	0.87	0.56	0.88	0.56
Riboflavin-deficient	1	4.56	3.51	6.29	4.79	3.90	7.14	5.48
	1**	4.56	3.00	3.16	3.57	7.78	12.36	9.07
Choline-deficient	2	3.43	1.63	2.89	2.65	5.32	6.39	7.12
				Riboflavin				
Control	2	14.37	31.36	20.57	22.10	—	—	2.82
Thiamine-deficient	2	14.13	30.60	21.44	22.06	2.69	2.44	7.44
Riboflavin-deficient	1	7.78	13.59	19.49	13.62	1.98	1.62	2.45
	1**	17.61	83.59	30.45	43.88	2.38	4.17	5.68
Choline-deficient	2	12.66	20.66	20.79	18.04	2.57	3.21	2.45

* Analyses in micrograms per gram.

** Analyses for sow which was turned out to pasture for 3 weeks before slaughter.

TABLE 5. AVERAGE THIAMINE* AND RIBOFLAVIN* ANALYSES OF BABY PIGS IN 1946 TRIALS

Lot	No. of pigs	Thiamine	Riboflavin
Control	3	2.51	2.83
Thiamine-deficient	2	0.34	2.55
Riboflavin-deficient	2	2.65	1.08
Riboflavin-deficient pigs removed from uterus	2	0.71	0.95
Choline-deficient	2	2.26	4.27

* Composite (whole pig) samples. Analyses in micrograms per gram.

litters were obtained from two control gilts which had been fed the purified ration only during the last 52 days of gestation. These gilts farrowed litters in a normal gestation period of 114 and 112 days, and raised thrifty litters of 8 and 6 pigs each with an average of 42-day weaning weight of 30.6 and 21.8 lbs. respectively. At weaning time, the pigs compared favorably in weight and appearance to pigs of comparable age from sows fed the regular natural ration fed the college herd.

The third control gilt to farrow had been on the purified ration for 140 days prior to farrowing. She gave birth to a litter of 10 pigs, 7 of which died at birth or immediately afterwards, while 2 more failed to survive 24 hours. This would seem to indicate that the purified basal ration when fed over a long period of time is deficient in some factor or factors required to support reproduction and lactation. The sow is apparently able to store this factor or factors for a considerable length of time as evidenced by the normal litters raised to normal weaning weights when the sows were fed the purified ration for only 52 days prior to farrowing. That storage for a considerable length of time of factors needed for reproduction and lactation occurs in the sow was conclusively shown by Cunha *et al.* (1944), Cunha *et al.* (1946) and Krider *et al.* (1946 *a*).

Thiamine-Deficient Gilts

In the 1945 trials, on several occasions during the gestation period, the gilts lost their appetites and it was only after the injection (subcutaneously) of 35 to 40 mg. of thiamine for several days that they regained their appetites. These injections had to be repeated in 8 to 10 days. The appetites of the gilts never failed following parturition and they ate all the feed allowed them.

One gilt farrowed 11 days ahead of the normal 114 days' gestation period and the other 9 days early. The litters farrowed by both gilts were generally characterized by a weak-legged condition, including buck knees, cow hocks, spraddled hind legs and cocked rear pasterns (figure 1). Abnormalities about the legs and feet were the chief complications noted among these pigs.

From the 42nd to the 54th day after birth, three pigs in each litter were given 9 mg. of thiamine every second day. No apparent benefit on growth or external appearance was obtained from these injections. Weaning weights of the pigs were considerably below normal, and their hair coats and general appearance became increasingly rough toward the end of the suckling period.

In 1946, it was decided not to give the gilts any injections of thiamine, if they lost their appetites, but rather to let the depletion run its course. In no case did the gilts go entirely off feed. Sow 552 failed to farrow, apparently

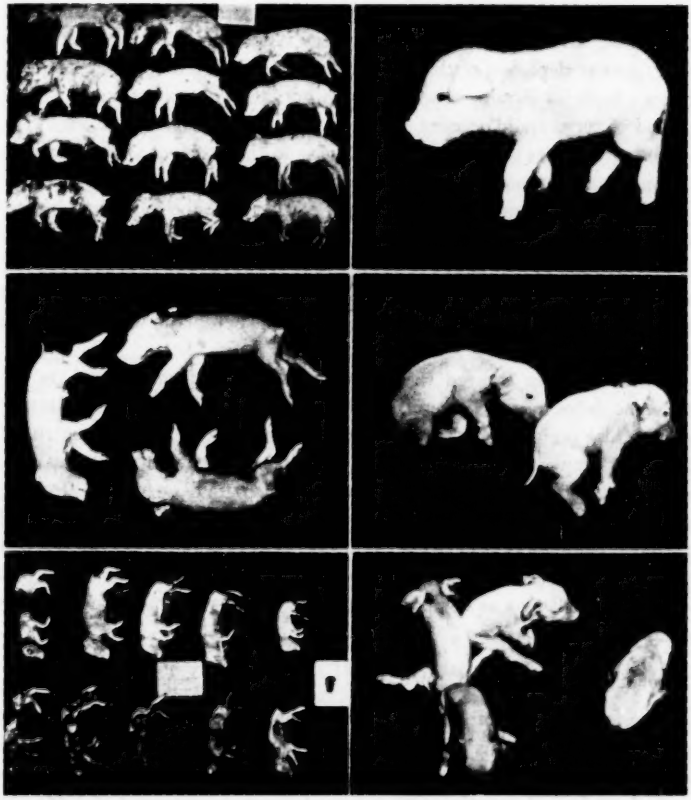

Figure 1. Three pictures on the left are from litters of riboflavin-deficient sows. Upper left, litter from riboflavin-deficient sow No. 551—note enlarged front legs and generalized edema in some pigs. All pigs were born hairless. Center left, three pigs from riboflavin-deficient sow No. 338—note enlargement of legs in two pigs as compared to normal pig. No pigs were hairless. Lower left, litter from riboflavin deficient sow No. 569. This litter was in the process of resorption. All pigs were hairless. The pictures on the right are of pigs representing leg weaknesses obtained with sows on rations where choline or thiamine was omitted.

not having conceived. Sow No. 571 gave birth to a litter of eight pigs all of which were dead at birth or died within 12 hours. The only pig with strength enough to stand showed spraddled hind legs. The other pigs lay kicking and gasping for breath. Sow 571 received the purified ration for 96 days prior to farrowing. This was over 20 days longer than the thiamine

deficient gilts were fed the same ration in 1945. As the young pigs appeared to be in an advanced stage of the deficiency symptoms noted in the previous year, greater depletion of thiamine and a possible lack of another factor or factors (same as shown to be lacking in gilts fed control ration for a long period of time) could account for the complete mortality of the pigs. The failure of the gilts to lose their appetite, as in the previous years, seems inconsistent and cannot be explained from present data.

Post-mortem examination of the small pigs showed the following: hemorrhage of the stomach, yellowish areas in the liver, hyperemia of the kidneys and lymphatic system and petechial hemorrhages of the heart. On microscopic examination the following was observed: kidneys showed hyperemia and hemorrhage, and the liver cells showed a pale cytoplasm with no obvious droplets or granules.

Tissue analyses showed that gilts which had been maintained on the thiamine deficient ration were very low in stored thiamine. Low thiamine storage also occurred in their young pigs. The average thiamine content of the ham samples (biceps femoris) of the thiamine deficient gilts was 0.56 microgram per gram as compared to 7.83 micrograms per gram for the control gilts. Heinemann *et al.* (1946) obtained values of 1.64 micrograms of thiamine per gram of ham tissue (biceps femoris) in young thiamine-deficient pigs. There appeared to be no change in the riboflavin content of the gilts or of the small pigs as compared with the content of this vitamin in the control sows and litters.

Riboflavin-Deficient Gilts

The four gilts in both trials developed almost a complete loss of appetite on numerous occasions after 38 to 54 days on the deficient ration. Large doses (35 to 40 mg.) of thiamine were injected subcutaneously during these periods of loss of appetite with apparent beneficial results. Gilts 551 and 569 on the riboflavin deficient ration in the 1946 trials were brought back on feed after a partial loss of appetite by injections of 35 to 40 mg. of thiamine for 2 or 3 days after which their appetite would remain normal for several days. Similar treatment on gilts 338 and 357 in the 1945 trials produced the same result. In other words, the gilts fed the riboflavin deficient ration seemed to require more thiamine in the ration than any of the other groups of sows.

With the riboflavin deficient gilts, in no case did any pigs born alive survive more than 20 to 48 hours. The longer the period of depletion, the more severe the deficiency symptoms became. Of the four gilts involved in the two years' trials, one farrowed 16 days early, one 9 days early, and one four days early, counting 114 days as normal gestation, and the other failed to

farrow and began resorbing her litter. Twenty three of the 30 pigs farrowed by the 3 gilts were born dead and the remaining 7 died within 20 to 48 hours after birth. Two of the pigs (figure 1), in the litter of gilt 338 had enlarged forelegs (enlargement due to gelatinous edema in the connective tissue). Both of these pigs with enlarged forelegs were still-born. One pig had a severe umbilical hernia but lived for 48 hours. The other pigs in this litter appeared normal. The litter of gilt no. 357 appeared normal on observation at birth, but all the pigs were too weak to suckle. Sow 551 gave birth to 12 hairless, dead pigs. Seven pigs (figure 1), had enlarged forelegs (due to gelatinous edema of the connective tissue). None of the pigs which had enlarged front legs showed enlargement of the bone. The enlargement of the forelegs, obtained in these 1945 and 1946 trials, resembles those described in pigs by Warwick, Chapman and Ross (1943) and suggested as possibly being due to genetic inheritance, but it is difficult to attribute to inheritance the enlarged front legs obtained in this work. All the gilts in each year's experiment were bred to the same boar. In both years' work, only the riboflavin deficient gilts had pigs with enlarged front legs. In the 1946 trials, littermate gilts were included in the four lots. Again only the gilts on the riboflavin deficient ration had pigs with enlarged front legs. Some of the pigs showed a generalized edema (figure 1). On post mortem all pigs showed some of the following: pale kidneys, mottled with congested areas and yellow granular accumulations, yellow friable livers, red areas in the stomach, and excess body fluid. On microscopic examination the following was observed: hemorrhage and marked hyperemia of the kidneys, hemorrhage and edema in the lymph nodes, numerous coase granules and cytoplasm of the liver cells, and marked edema of the subcutis of the legs.

The litter removed from the uterus of sow 569, fourteen days after her normal farrowing date, were also hairless and this was apparently not due to their stage of development. The fetuses appeared to have died at about the normal time for parturition and had begun to atrophy. Two pigs showed edema of the front legs and one showed generalized edema. It is difficult to explain why hairless pigs were obtained from the riboflavin deficient sows only during the 1946 trials. The hairlessness would appear not to be due to a lack of iodine since none of the other sows, getting the same source and approximately the same amount of iodine, did not farrow hairless pigs. The hairlessness might be due to a more severe deficiency of riboflavin since the sows in 1946 were kept on the riboflavin deficient ration for a longer period of time.

The riboflavin-deficient gilts gave birth to pigs very low in riboflavin. The one riboflavin-deficient gilt on which analyses were conducted, was considerably below the control gilts in riboflavin storage. The other riboflavin-

deficient gilt was on pasture three weeks between farrowing and slaughter and thus her analyses are not comparable. It is of interest to note that in three weeks time on pasture the riboflavin storage of this gilt rose far above that of the control gilts. There seems to be no definite interrelationship between thiamine and riboflavin in the analyses obtained on the gilts. In the case of the riboflavin deficient gilt which began to resorb her litter, the pigs were found to be very low in thiamine as well as riboflavin. The other litter was normal in thiamine content.

Choline-Deficient Gilts

All four of these gilts farrowed at the end of a normal gestation period. With the exception of the weak leg condition, which was apparent in most of their pigs (figure 1), fairly good litters were obtained from sows No. 351 and 402. Half of these pigs were given injections of choline every second day from the 42nd to 56th days. No benefit was derived from these injections of choline insofar as appetite or increased gains in body weight were concerned. The weaning weights of these pigs were much below normal and some of the pigs were rough in appearance, becoming increasingly so with age.

In the litters of sows 567 and 574 a shaking of the body and head due to some muscular or nervous incoordination was observed. In the two pigs which lived, this shakiness continued until about the fourth week and then disappeared. Kinked tails were in evidence in both litters; Cunha *et al.* (1944) observed similar kinked tails in pigs from sows fed a natural ration deficient in certain factors. Four pigs in the litter of sow 574 had spraddled hind legs. Two pigs were very sensitive to handling in this litter. There was very heavy mortality in both litters and only one pig in each litter survived past 72 hours. The weaning weights of the two surviving pigs were high, but of no significance as they were the only pigs suckling each sow. A rough hair coat developed as they became older. These two pigs were carried on a choline deficient ration for approximately 70 days after weaning (Cunha, Hart and Ensminger, 1946). They developed very rough hair coats and an autopsy showed very fatty livers.

Post-mortem and microscopic examinations of the small pigs farrowed by the choline deficient gilts showed the following: fatty livers, congestion and petechial hemorrhages of the kidneys, and yellow granular accumulations in the kidneys, and two pigs showed an inflamed vulva.

Analyses of thiamine in the tissues of the choline-deficient gilts showed a somewhat lower amount of thiamine in comparison to the amount contained by the control gilts. This amount was lower in the internal organs. There was very little difference in the riboflavin content of the tissues when these

gilts were compared to the control gilts. In the young pigs, thiamine was the same and the riboflavin content was higher than that of the pigs from the control gilts.

Summary

Some factor or factors, either one or more of the other known B-complex vitamins not included in the purified ration used, or some unknown factor(s) is essential for reproduction and lactation in swine. The storage of this factor or factors in the sow must be sufficient to carry her for a long period of time as evidenced by the good record made by the two control gilts which were fed the purified basal ration (supplemented with the fat soluble vitamins (A, D, E, K) and the six B-complex vitamins: thiamine, riboflavin, niacin, pyridoxine, pantothenic acid, and choline) only during the last 52 days of gestation and through a lactation period of 42 days, whereas complete failure in lactation was obtained when the same ration was fed for 140 days prior to farrowing.

The deletion from the ration of any one of the three B-complex vitamins, thiamine, riboflavin, or choline, resulted in unsatisfactory reproduction and lactation. These results most likely are all complicated by an incomplete control ration so the following data obtained cannot be stated to be due to an uncomplicated single vitamin deficiency:

(A) Results with gilts fed ration with no thiamine added: (1) Some loss of appetite, but not consistent; (2) Efficient feed utilization obtained during pregnancy; (3) Parturition 9 and 11 days prematurely in two cases; (4) High birth mortality in litters; (5) Weak-leg condition in pigs at birth; (6) Unthrifty pigs and subnormal weaning weights. Postmortem and microscopic data are given. (B) Results with gilts fed ration with no riboflavin added: (1) Erratic or, at times, a complete loss of appetite in pregnant gilts which was restored by injections of thiamine; (2) Poor gains; (3) Parturition 4 to 16 days prematurely; (4) One case of death of fetus in advanced stage with resorption in evidence; (5) All pigs were either dead at birth or died within 48 hours thereafter; (6) Enlarged front legs, due to gelatinous edema in the connective tissue in 9 pigs, and generalized edema in many pigs; (7) Two hairless litters born. Postmortem and microscopic data are given and discussed. (C) Results with gilts fed ration with no choline added: (1) Appetite of sows good; (2) Gilts farrowed on schedule; (3) At birth, many of pigs showed weak leg conditions such as those observed on thiamine deficient ration. (4) Muscular incoordination was observed in some pigs; (5) Heavy mortality in pigs and subnormal weaning weights; and (6) Fatty livers in pigs. Additional postmortem and microscopic data are given.

Cases of hernia, kinked tail, enlarged forelegs, liver and kidney abnormali-

ties occurred in pigs farrowed by various of the sows receiving the purified rations. The use of litter mate gilts in the 1946 trials and the normal appearance of the pigs from the control gilts seem to limit the abnormalities being due to genetic variation. The weak legged condition and general weakness at birth of pigs was so prevalent that it appeared to be nutritional. It would seem that much of the variation in severity of abnormalities could be attributed to differences in the length of time the sows were fed the purified ration and therefore variation in the amount of depletion of the factor(s) involved.

Results of analyses of certain tissues for riboflavin and thiamine, of the gilts and pigs used in the 1946 trials, are given and discussed.

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THE RELATION BETWEEN AVERAGE DAILY GAIN AND SOME CARCASS MEASUREMENTS[1]

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MANY carcass studies have been made correlating the kind and amount of feed used with the quality of the finished animal and the carcass that was produced. Few attempts, however, have been made to study the relation between growth, feed utilization, and carcass characteristics as they are influenced by the breeding of the animals. Lush (1936) analyzed Danish swine production from a genetic standpoint. Dickerson (1947) studied the relation between carcass composition and rate and economy of gain in purebred Poland China and Poland China-Danish Landrace swine.

The object of the present study was to estimate the heritability of rate of gain, fatness and carcass, and skeletal and muscular development, as well as to determine the relation between gain and the other characters in partially inbred lines of Duroc-Jersey swine.

Materials and Methods

Animals used in this study were raised as part of the Nebraska project of the Regional Swine Breeding Laboratory. The management of this herd has been described by Baker *et al.* (1943). Most of the carcasses, 358 out of 416, were from animals that had been on Record of Performance tests. The remaining 58 carcasses were from litter mate pigs that received the same ration but were fed out in larger groups and were not weighed every 28 days. These 58 carcasses were included in the analysis of depth of back fat and length of hind leg only.

No anlaysis was made of the amount of feed required per 100 pounds of gain. Animals on the record of performance tests were fed out in groups of four, so that only the average feed consumed for the lot could be assigned to each animal. Such a procedure might be justified if all the animals in a test lot were slaughtered. Replacement gilts were taken from the test lots so that in many instances only one or two animals from the group of four were slaughtered. The use of feed records therefore was considered of doubtful value.

The animals were removed from the R.O.P. tests as they reached approxi-

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mately 225 pounds, and were slaughtered at a local packing plant. Range of final weight was from 208 to 255 pounds, whereas the average slaughter weight was 224.3 pounds.

Carcasses were obtained over a space of five years and represented eight farrowing seasons. The same measurements were not taken in all seasons, so that the number of seasons, litters, and sires varied somewhat for the different items studied.

Items studied and symbols used to represent them in the following tables were as follows:

G_1 = the average daily gain from weaning (56 days) to 112 days of age.
G_2 = the average daily gain from 112 days of age to the time of slaughter.
G_3 = the average daily gain from 56 days of age to the time of slaughter.
F = depth of back fat.
L = length of hind leg.
H = circumference of ham.

The feeding period was divided roughly into two portions so that the gain made during the growing period (56 to 112 days) could be separated from the gain made during the fattening period (112 to end). McMeekan (1940) states that most of the pigs' skeletal and muscular growth is made during the first 116–120 days and after that most of the increase in weight is due to fat deposition.

Depth of back fat was measured at the level of the seventh rib. In most instances the figure used was the average of the measurements taken on the right and left halves of the carcass. Ellis and Hankins (1937) suggest the use of this measurement because it is easy to locate anatomically and has a relatively high predictive value.

Length of hind leg was measured from the hoof head (coronary band) to the lower edge of the aitchbone as the carcass was hanging on the rail.

Circumference of ham was taken midway between the bony prominence on the inside of the hock joint and the lower edge of the aitchbone. It is realized that the circumference measurement is influenced by both the size and shape of the muscles as well as by the amount of fat covering the ham. This measurement was used as an index of muscling.

Analyses of variance and covariance made on the data followed the methods given by Snedecor (1946). The general form of the analyses is the same as that used by Hazel *et al.* (1943) in their analysis of growth rates of this same herd of swine.

Data and Discussion

The means of the different items studied are given in table 1. Average daily gain for the whole period (G_3) was calculated from the original data.

As was expected, rather large seasonal differences were found in all the items. This was especially true of the length of hind leg. There was a change in the method of measuring leg length between the first and succeeding seasons, which would account for the great difference that was found in these measurements.

TABLE 1. MEANS OF THE CHARACTERISTICS BY SEASONS AND YEARS

Season	Animals or carcasses	Average daily gain			Measurements		
		G_1	G_2	G_3	F	L	H
	number	*pounds*	*pounds*	*pounds*	*inches*	*inches*	*inches*
1937 Spring	81	.93	1.68	1.38	1.74	25.0	
Fall (a)[1]	59	1.19	1.84	1.54	1.67	22.7	
(b)	117			1.55	1.72	22.6	
1938 Spring	23	1.28	1.70	1.52	1.96		18.3
Fall	56	1.08	1.68	1.44	2.03	23.5	17.9
1939 Spring	43	1.17	1.66	1.44	1.92	23.0	17.8
1940 Fall	36	1.35	1.95	1.65	1.99		20.2
1941 Spring	34	1.05	1.55	1.35	1.92		19.4
Fall	26	.86	1.61	1.32	1.86		19.9
Total or mean for:							
G	358	1.10	1.72	1.45			
F	416				1.85		
L	297					23.5	
H	218						18.8

[1] (a) includes record of performance animals only, while (b) includes all animals slaughtered.

The analyses of variance are given in table 2. Each of these analyses is based on the greatest number of carcasses possible so that the available degrees of freedom for testing significance would be a maximum. In these analyses the mean square between litters was used as the error term for testing the significance of the sire and line mean square.

A highly significant difference was found between litters within sires for

TABLE 2. ANALYSES OF VARIANCE OF THE CHARACTERISTICS. (MEAN SQUARES ONLY)

Source and symbol		F		Average daily gain				L		H	
		Df.	M.S.	Df.	G_1	G_2	G_3	Df.	M.S.	Df.	M.S.
Seasons	*T*	7	.858***	7	1.081***	.621***	.471***	3	93.80***	5	40.90***
Sires and line	*S*	40	.118*	40	.077*	.070*	.034*	20	1.42**	31	.79*
Between litters	*D*	111	.090***	107	.052**	.051**	.023**	80	.76***	71	.57
Within litters	*A*	257	.044	203	.039	.034	.017	193	.39	110	.49

*=P<.10, **=P<.05, ***=P<.01.

both depth of back fat and length of hind leg. A significant difference was found for G_1, G_2, and G_3 between litters within sires; whereas no difference between litters within sires was found for the ham circumference measurement. The variance between sires was significant for leg length but not for any of the other characteristics. The mean squares for between sires, however, were larger than the mean squares between litters. This probably indicates a sire influence throughout, although a much larger group of data would be necessary to establish its significance.

Ham circumference is a function of both the size of the muscles and the amount of fat covering the ham. An increase in either or both of these factors may cause a difference in *H*. Hiner and Hankins (1939), studying four muscles in their relation to ham conformation, found that the muscles did not consistently increase or decrease in weight with the increase in ham plumpness. They also found that the percentage of separable fat and plumpness were positively correlated, whereas the correlation between plumpness and separable lean was negative. The correlation between separable fat and separable lean was very high and negative. With an automatic negative relationship, fat and muscle apparently counterbalanced each other in these data. As a result, individual variation was so great that it masked any differences between litters.

Relative importance of the different sources of variation contributing to the mean squares of table 2 was determined. The theoretical composition of the mean squares was estimated by the method of Stonaker and Lush (1942) and is given in table 3. Various factors contributing to the mean squares were as follows:

A = variance from differences between litter mate pigs. This includes environmental and genetic differences between litter mate pigs.

D = variance from differences between litters within sire, line, and season. This includes any environmental differences between litters (direct maternal influence), as well as the extra genetic variance caused by the pigs being paternal half-sibs instead of full sibs.

S = variance from differences between groups of sire progeny within a season. This includes the extra genetic differences that come from the animals being non-sibs instead of paternal half-sibs, as well as any genetic difference between lines. These were probably small in these data.

Υ = variance from differences between means of seasons. This includes any changes that might have occurred in the method of feeding or weighing the animals or measuring the carcasses, as well as any changes in average environmental effects from season to season, plus any genetic changes that might have taken place.

Baker *et al.* (1943) and Hazel *et al.* (1943) analyzed the growth rates of pigs in this herd. From their analyses it was determined that S and A each contained about 40 percent of the additively genetic variance, while *D* contained the remaining 20 percent. Their analyses were based on a larger unselected population and contained the majority of the animals used in this study.

Results of these earlier calculations were applied to the present data and the heritability estimates thus obtained are given in the lower part of table 3.

TABLE 3. ESTIMATES OF VARIANCE COMPONENTS AND OF HERITABILITY

Component of mean square	Character studied					
	F	G_1	G_2	G_3	*L*	*H*
A. Estimates of variance components						
Source						
Season (*Y*)	.0142	.0224	.0123	.0098	1.2242	1.1090
Sires and line (*S*)	.0032	.0034	.0025	.0015	.0533	.0376
Dam (*D*)	.0176	.0056	.0074	.0026	.1296	.0398
Littermates (*A*)	.0440	.0390	.0340	.0170	.3900	.4900
B. Estimates of heritability of intra season variation*						
Heritable differences	.123	.177	.142	.178	.233	.166
Non-heritable differences						
Between litters	.247	.081	.140	.088	.180	.037
Within litters	.630	.742	.718	.734	.587	.797

* Based on the following values determined by Baker *et al.* (1943): Hereditary portion = 2.5*S*; Portion due to litter environment = *D* − 0.5 *S*; Portion due to environment peculiar to the individual = *A* − *S*.

It is realized that this procedure probably introduces some error, but the results should be comparable for the characteristics studied here.

The heritability estimate for G_1 was approximately 18 percent and for G_2, 14 percent. Hazel *et al.* (1943) found heritability to be 28 and 17 percent, respectively, for the two comparable periods. Differences between the two sets of values is not surprising when the difference in size of the two populations is considered. Then, too, the present animals were not considered suitable for use in the breeding herd and probably represent the poorer type animals of the previous analysis.

Dickerson (1947) found *F* and *L* to be much more highly heritable than the estimates of 12 and 23 percent obtained in this study. Dickerson's figures were based on measurements made on another breed, so that the difference

between his results and the present values might be due, in part at least, to breed differences.

The heritability of *H* is 4.3 percent greater than that of *F*. Some increase in heritability might be expected in this case unless a negative genetic correlation exists between fat and muscle. No attempt has been made to determine the portion of the heritability of *H* that is due to fatness and that due to muscle, nor the genetic correlation between them.

Environmental differences between litters varied from 3.7 percent for *H* to about 25 percent for *F*. These differences are in part a measure of the influence of the dam on her litter. Unequal sex distribution in the different test lots which were made up of individual litters might also have influenced the between-litter variance. Not enough gilts were slaughtered to warrant making the analysis on a within-sex basis.

TABLE 4. CORRELATIONS BETWEEN GAIN (*G*) WITH DEPTH OF BACK FAT (*F*), LENGTH OF HIND LEG (*L*), AND HAM CIRCUMFERENCE (*H*)

Source	Df.	FG_1	FG_2	FG_3	Df.	LG_1	LG_2	LG_3	Df.	HG_1	HG_2	HG_3
Seasons	7	.303	−.147	.083	3	−.993**	−.522	−.884*	5	.401	.380	.195
Sires and line	40	.243	.216	.328*	22	−.272	−.253	−.264	31	.014	.367	.280
Between litters within sires	107	.103	.473**	.464**	74	.035	−.124	−.091	71	.279*	.287*	.206
Within litters	203	.087	.422**	.292**	139	.084	−.164*	−.066	110	.056	.096	.106
Total	357	.167*	.285**	.290**	238	−.347**	−.240**	−.356**	217	.078	.222**	.180*

*=P<.05, **=P<.01.

Environmental differences between litter mate pigs were large, varying from 59 per cent for *L* to 80 percent for *H*.

Correlation coefficients between gain and depth of back fat, length of hind leg, and ham circumference are given in table 4. The correlations between rate of gain and depth of back fat are in general low and positive while those for rate of gain and length of hind leg are low and, for the most part, negative. The correlations between ham circumference and gain are positive but most of them are insignificant.

The value of r_{FG_1}, both within and between litters, is lower than that of r_{FG_2}. On the other hand, r_{LG_1} is positive, while r_{LG_2} is negative. These results were to be expected, for during the first period gain is largely a measure of increase in muscle and bone size. During the second period, however, increases in muscle and bone size are not so important as increases in fat deposition in determining gain. Therefore, the relation between *F* and G_2 should be greater during the second period than during the first period. The relation between *L* and G_2 is negative in the second period. That is, the ani-

mals making the least skeletal growth were making the largest gains. These gains were mostly due to increases in the amount of fat the animal was putting on.

For sires within seasons the order of the correlations FG_1, FG_2, and LG_1, LG_2 is the reverse of those between and within litters. The variance and covariance for sires within seasons includes heritable differences in the dam's direct maternal influence as well as the pig's own genetic tendencies. Any correlation between these two kinds of genetic influence is fully represented in the sire differences. From the previous work of Baker *et al.* (1943) and Hazel *et al.* (1943), it was found that the dam's influence on rate of gain was high at the early ages and tended to be less important as the pigs grew older. A tendency for the lines with good suckling ability to be inherently slower fatteners (lower in G_2) could account for r_{FG_2} being smaller than r_{FG_1} and lower among sire progenies than among litters of the same sire. However, Dickerson (1947) found r_{FG_3} to be positive and larger among line means than among means of sire progenies within line and year.

Correlations between gain and ham circumference are about the same size for the two periods. During the first period the correlation probably measures the relation between gain and increase in muscle size, while during the second period it is more a measure of the relation between gain and fat deposition.

Differences between sire progenies are more largely genetic than those between litters by the same sire. The direction and significance of the correlations between these heritable deviations are indicated by the simple correlations given in table 4. The covariances upon which these correlations were based were separated into their component parts in order to determine the genetic correlations. None of these estimates of genetic correlation was large enough for statistical significance.

The indicated genetic correlation between depth of back fat and gain was positive during the first period (G_1) and negative during the second period (G_2). The value of the genetic correlation when the whole feeding period was considered was slightly negative ($-.04$). For length of hind leg and gain, a negative genetic correlation was found for G_1, G_2, and G_3; whereas a positive correlation was found between gain and ham circumference.

It is realized that one important factor necessary for a complete picture is lacking for the present data. Feed consumption has not been taken into account and of course the amount of feed consumed per 100 pounds of gain is an important factor in economical hog production.

These results with Duroc-Jerseys indicate less genetic but more environmental association between rapid gains and fatness than was reported in Poland Chinas by Dickerson (1947). This may indicate a breed difference in the relation between fatness and rate of gain.

Summary

Carcass data on 416 animals were studied to determine the relative importance of hereditary and environmental factors which affect depth of back fat, length of hind leg, ham circmuference, and average daily gain from weaning to slaughter. The feeding period was divided into two portions so that the relation between gain and the other characters could be studied during the growing as opposed to the fattening period.

Hereditary factors accounted for 12 percent of the variance for depth of back fat and 23 percent of the variance for length of hind leg. The estimates of heritability for the other characters were between these two extremes.

Relative importance of litter environment varied from 3.7 percent for ham circumference to about 25 percent for depth of back fat.

Environmental factors peculiar to the pigs varied from about 59 percent for leg length to 80 percent for ham circumference.

Simple correlations between gain and depth of back fat and gain and ham circumference were low and positive, while that between gain and length of hind leg was negative. Genetic correlations were not significant but indicated a negative correlation between gain and depth of back fat and length of hind leg, but a positive genetic correlation between gain and ham circumference.

These results with Duroc-Jersey swine seem to indicate less genetic but more environmental association between rapid gains and fatness than has been found in Poland Chinas. This may indicate a breed difference in the relation between fatness and rate of gain.

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DIGESTIBILITY OF RATIONS FOR RUMINANTS AS AFFECTED BY PROPORTIONS OF NUTRIENTS[1]

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A PROBLEM of fundamental significance in the nutrition of farm animals concerns the effect of combining feed components into rations. The general subject of feeding stuff composition as affecting digestibility has been one of concern to students of animal production since the beginnings of agricultural research, but has been one of baffling difficulty for the fundamental reason that it has been impracticable to reduce the experimental backgrounds to single variants, and especially to isolate the antecedent and the end products of the metabolism of the microorganisms of the alimentary tract.

The main objective of this investigation was to determine the effects of supplements on the apparent digestibility of a ration, each supplement representing one of the following: crude fiber, ether extract, protein, carbohydrate, and urea. Conditions which were considered advantageous to the project were that the entire subject (superficially speaking) was covered in one experimental program; the same animals were used as subjects in the basal and the supplemental periods of each determination of digestibility; the nutritive substances studied were added to the basal rations in two quantities; and the experimental routine had been subjected to an extensive preliminary trial, on a single ration, with statistical treatment of the results (Forbes *et al.* 1946).

In the planning of this investigation a critical consideration was the method by which the rations should be varied in their contents of the nutrients being studied—whether the test nutrients should be added in pure form or whether supplements should be used which were rich in the nutrient in question. The use of the nutrients in pure form had in its favor the fact that by this method the rations compared would differ in one constituent only, but had against it the fact that the test nutrients would not be in their natural physical and chemical relationship in foods, and that on this account the results obtained might not be true of the test nutrients as naturally contained in foods. Inevitably, the addition of any supplement causes a change in the percentage composition of the ration regarding every nutrient therein. With the exception of the crude fiber test, however, the amounts of supplements were not very great. Crude fiber was supplied in a naturally

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occurring state (oat straw) while the 5 other supplements were given as practically pure chemical compounds.

Experimental

Fifteen Hampshire wether lambs were selected from a group of twenty on the basis of uniformity of live weight and regularity of feed consumption and were then divided into groups of five, each such group to serve as a unit in the measurement of digestibility.

In order that the validity of results should not be jeopardized by parasitic infestation, two weeks before the beginning of the experiment each sheep was given a drench of 4 ounces of a phenothiazine preparation, containing 25 grams of phenothiazine. During the digestion trials, each sheep received common salt at the rate of 1 teaspoonful per day, with no phenothiazine, while during the intermediate rest periods the animals had free access to a 1:9 mixture of phenothiazine and salt. This method of control of intestinal parasites had proved to be very effective in a previous experiment (Forbes *et al.*, 1946).

Each experimental period consisted of a preliminary period of 10 days during which the sheep were fed quantitatively in the digestion crates, followed by a 10-day collection period with the sheep still in the crates, and a 10-day rest period during which the sheep had the freedom of a feeding shed. The digestion crates, harnesses, and feces collection bags used were as described in an earlier paper (Forbes *et al.* 1946). The average live weight of the sheep during the 22 weeks of the experiment increased from 83.6 pounds to 125 pounds.

The schedule of experimentation is given in table 1. Each experimental period involving the maximum amount of supplement preceded the one of lesser amount which in turn was followed by the basal period. The object of this order was to reduce the probability of feed refusal as the experiment progressed. The same group of sheep was used in each such set of 3 experimental periods.

The hay was a second cutting mixture of alfalfa and timothy, of excellent uniform quality which had been barndried over flues without heat. The sheep were fed twice each day, the five sheep on a given treatment receiving equal amounts of feed. Water was available at all times. The feces collection was virtually perfect. Collection was made twice each day. The feces were dried in a Freas oven in a current of air at 55° C. for 24 hours, and were then removed and allowed to air-dry at room temperature for a week. The half-day portions from each sheep were combined, making a 10-day composite for each animal. After air-drying at room temperature, the feces composites were weighed and ground for analysis. The urine was not collected.

About one week before the beginning of each collection period the individual rations for the remainder of the 10-day preliminary period and for the collection period to follow were prepared. All feeds were sampled at the time the weighings were made.

In order to assure that each portion of feed contained the exact and small amount of supplement desired, a mixture containing the required amounts

TABLE 1. SCHEDULE OF EXPERIMENTATION AND COMPOSITION OF RATIONS

Period No.	Sheep group No.	Collection period		Rations fed daily								
		Start	End	Mixed hay	Corn meal	Linseed oil meal	Oat straw	Starch	Corn sugar	Casein	Urea	Corn oil
				gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.
1	1	Oct. 29	Nov. 8	340	510	48	222					
4	1	Nov. 28	Dec. 8	340	510	48	111					
7	1	Dec. 28	Jan. 7	340	510	48	0					
5	2	Dec. 8	Dec. 18	420	420	48		72				
8	2	Jan. 7	Jan. 17	420	420	48		0				
3	3	Nov. 18	Nov. 28	420	420	48			130			
6	3	Dec. 18	Dec. 28	420	420	48			75			
9	3	Jan. 17	Jan. 27	420	420	48			0			
10	1	Jan. 27	Feb. 6	420	420	48				116		
13	1	Feb. 26	Mar. 8	420	420	48				58		
16	1	Mar. 28	Apr. 7	420	420	48				0		
11	2	Feb. 6	Feb. 16	420	420	48					8.8	
14	2	Mar. 8	Mar. 18	420	420	48					4.4	
8	2	Jan. 7	Jan. 17	420	420	48					0	
12	3	Feb. 16	Feb. 26	420	420	48						68
15	3	Mar. 18	Mar. 28	420	420	48						34
9	3	Jan. 17	Jan. 27	420	420	48						0

of supplement, corn meal and linseed oil meal, was prepared in an amount sufficient for the entire period. After thorough mixing in an electric mixer, individual feed portions of the mixture were weighed to the nearest gram and added to the hay portions in paper bags.

These individual feeds (hay and concentrate) in paper bags were then stored in large cans. This procedure was followed in all periods except the two involving the feeding of corn oil. Since it was found that considerable fat would be absorbed by the paper bag, the mixture of corn, linseed meal and corn oil was made up for the entire period and stored in large tin cans, the individual portions being weighed out each day as needed at feeding time.

The original plan of the investigation called for a total of 16 experimental

periods with five sheep each. However, the sheep would not eat the maximum amount of starch offered and period 2 had to be abandoned. Four out of five sheep completed period 5 in which a smaller amount of starch was offered. It was surprising that the sheep refused the starch supplement whereas they readily consumed the cerelose. It appeared that the starch, even though mixed with the corn and linseed meal, contributed a distasteful character to the ration. Also during period 6 one animal failed to clean up the ration containing cerelose and was taken off the experiment. One sheep refused feed in period 12 and consequently was not used in period 15. Thus, out of the proposed 80 10-day feces collection periods, 71 were completed.

Since only 4 sheep out of 5 completed the starch supplemented period (No. 5), the average values for the corresponding basal period (No. 8) were derived from the same 4 sheep only, even though good results from 5 sheep were obtained in the latter period.

The usual feeding stuff analyses were made by standard methods, while lignin was determined by the 72% H_2SO_4 method as recently modified by Ellis, Matrone and Maynard (1946).

Results

The composition of the feeding stuffs is given in table 2. One lot of each feed component except casein was used throughout the experiment. A separate sample of each was taken for each period at the time of weighing. The moisture content of the three components common to all periods was determined and, at the end of the experiment, the period samples of each of these 3 components were composited into one sample on the basis of dry matter content. This procedure was based on the assumption that the com-

TABLE 2. COMPOSITION OF FEEDING STUFFS

Feeding stuff	Dry matter	Composition of dry matter					
		Crude protein	Ether extract	Crude fiber	N-free extract	Lignin	Energy
	percent	*percent*	*percent*	*percent*	*percent*	*percent*	*cal./gm.*
Mixed hay	91.19	16.75	2.11	31.03	42.05	9.41	4502
Corn	86.41	9.63	4.27	2.49	82.13	.51	4565
Linseed oil meal	90.02	38.00	3.74	9.85	42.55	7.05	4805
Oat straw	90.50	4.13	1.38	48.87	40.76	13.42	4536
Starch	88.58	.49	—	—	99.51	—	4157
Cerelose	92.34	—	—	—	100.00	—	3695
Casein (period 10)	89.71	91.19	—	—	6.94	—	5687
Casein (period 13)	91.44	89.56	—	—	7.50	—	5609
Urea	99.64	265.19	—	—	—	—	2492
Corn oil	100.00	—	100.00	—	—	—	9382

position of the dry matter was constant throughout the time involved and that such a composite sample would most accurately represent the feed component as used in the experiment.

The percentage digestibility of the rations is given in table 3 and, except as otherwise noted, the values given are the averages for 5 sheep. Attention is called to the fact that the digestion coefficients given for period 9, when

TABLE 3. PERCENTAGE DIGESTIBILITY OF RATIONS

Period No.	Supplement	No. of sheep	Dry matter	Crude protein	Ether extract	Crude fiber	N-free extract	Lignin	Energy	Crude protein corrected for metabolic nitrogen
			percent	*percent*	*percent*	*percent*	*percent*	*percent*	*percent*	*percent*
1	Straw (max.)	5	66.9	62.2	59.5	44.8	78.0	−2.0	65.1	68.1
4	Straw (½ max.)	5	71.5	65.5	63.0	47.0	88.2	5.0	69.4	68.6
7	Basal	5	78.4	70.6	69.8	51.4	88.2	2.7	76.6	70.6
2	Starch (max.)	—	—	—	—	—	—	—	—	—
5	Starch (½ max.)	4	74.9	67.1	63.3	45.9	86.0	4.2	73.3	69.0
8	Basal	4	74.8	70.2	62.2	49.7	85.3	−4.4	72.6	70.2
3	Cerelose (max.)	4	76.3	65.4	60.2	43.3	87.7	3.0	73.7	69.6
6	Cerelose (½ max.)	4	77.2	69.8	64.0	48.5	87.8	5.2	75.0	71.9
9	Basal	4	74.9	70.0	62.7	50.7	85.2	0.0	72.6	70.0
10	Casein (max.)	5	77.0	83.9	65.7	44.2	85.5	2.4	76.4	85.7
13	Casein (½ max.)	5	77.0	81.1	65.0	44.5	86.8	1.0	75.7	82.2
16	Basal	5	76.2	74.5	63.0	47.5	87.2	1.9	74.2	74.5
11	Urea (max.)	5	73.0	77.1	60.1	47.1	85.4	−2.4	72.8	77.3
14	Urea (½ max.)	5	75.2	74.6	59.1	49.4	85.5	−0.2	72.9	74.7
8	Basal	5	74.7	70.2	61.8	49.3	85.3	−6.2	72.5	70.2
12	Corn oil (max.)	4	72.8	67.4	85.9	40.7	81.5	−2.7	71.5	69.5
15	Corn oil (½ max.)	4	76.2	72.4	79.8	50.9	86.5	0.5	74.7	73.4
9	Basal	4	74.7	70.4	63.5	49.0	85.1	0.0	72.6	70.4

used as the basal period with the cerelose-supplemented periods, are not identical with those given for period 9 when used as a basal period with the corn oil supplemental periods. The reason for this is that whereas entirely satisfactory results were obtained from 5 sheep in period 9 (basal), the average of only 4 is used in order that the average figures pertaining to a particular supplemented ration and to the corresponding basal ration be derived from the same individual sheep. The one sheep which is omitted in the cerelose periods, and in the basal period compared with them was not the same individual which failed in the corn oil periods.

When all differences in results between a basal ration and a supplemented

one are ascribed arithmetically to the supplement, especially if the supplement is small, great magnification of error may occur. In such a comparison the assumption is made that the basal ration exerts identical effects in both trials. In the work herein reported comparison is made between the results of rations as fed.

The feeding of oat straw in two different amounts (table 3, periods 1 and 4) resulted in consistent decreases in percentage digestibility of each constituent of the supplemented rations as compared to the basal (table 3)—the only exception being the lignin, the digestibility of which was so nearly zero that relatively wide variations are of little significance.

Since diminished percentage digestibility of the supplemented ration may not signify a lesser absolute amount digested, reference is made to table 4 in order to evaluate the contribution of digestible nutrients by the oat straw. As would be expected the oat straw caused a considerable increase in the amounts of dry matter and crude fiber digested. However, it decreased the amounts of digestible protein and ether extract digested, the decrease in percentage digestibility (table 3) being more than enough to offset the increase in intake of these nutrients in periods 1 and 4. The digestible protein was 4.6 gms. less per day in period 1 (maximum quantity of oat straw) than in period 7 (basal), while the digestible ether extract decreased from 18.7 to 17.5 grams. The basal ration (period 7) contained 12.2% crude fiber. The addition of the larger amount of oat straw (222 gms. daily, period 1) which contained 48.9% crude fiber increased the digestible energy by 162 Cal. daily but decreased the apparently digestible protein.

All observed differences in digestibility of the dry matter, crude protein, and energy found between the two oat straw periods and between either one of these and the basal period are highly significant, as evaluated by the standards given in a recent paper (Forbes *et al.*, 1946) in which significant differences in percentage digestibility are given which must be obtained in accord with the number of sheep used on a treatment. In the interpretation and discussion of the results presented in this paper our interest is focused on the digestibility of protein and energy.

Attention is called to the column at the extreme right in table 3 in which the corrected coefficients for protein are given, these having been derived on the thesis that each 100 gms. of dry matter of the supplement caused an increase of .55 gm. of metabolic nitrogen in the feces (Harris and Mitchell, 1941*a*). There may be some question as to the validity of the application of this correction since one may argue that an increase of nitrogen in the feces caused by the added oat straw should be charged against it regardless of whether or not the increase in fecal nitrogen originated directly from the oat straw. Considering the corrected protein coefficients in table 3, there was a

significant difference (odds 19 to 1) in protein digestibility only between the basal period and the period in which the larger amount of oat straw was fed.

A pertinent question as to the correct interpretation of the protein digestibility coefficients concerns the relative effects on the metabolic fecal nitrogen of 100 grams of dry matter of oat straw containing nearly 50 per cent of crude fiber as compared to 100 grams of cerelose (corn sugar) which is entirely water soluble. Even if the effects of two such dissimilar supplements were equal and appreciable, the fact is, to quote Armsby (1917, p. 620) that, "Whether the increased excretion of nitrogenous matter in the feces after carbohydrate feeding be due to an apparent or a real depression of digestibility, or to both combined, it is none the less a loss of protein from the body." It is, "The apparent digestibility which measures the real advantage derived by the animal from the digestion of its feed."

Considering next the periods in which carbohydrates were fed as supplements, the one period (No. 5) in which starch was fed shows that this nutrient definitely depressed the digestion of crude fiber. This is in harmony with the results of previous investigations and is presumably due to the preference of the microorganisms for the simpler carbohydrate. Mitchell and Hamilton (1940) reported that when glucose was added to the basal ration of beef calves the digestibility of the insoluble carbohydrate was decreased; and working with sheep, Hamilton (1942) found that the addition of corn sugar decreased the total metabolizable energy of the ration. The only other significant effect of the added starch was the decrease in apparent digestibility of protein.

In the study of cerelose, the smaller amount of this carbohydrate resulted in a significant increase in the digestibility of the dry matter and energy of the ration with no significant change in the protein coefficient. But when the amount of supplement was doubled (period 3), the percentage (and amount) of protein digested was significantly less than in the basal period, with no appreciable change in the digestion coefficients for dry matter and energy. More evidence that the amount of a supplement may determine whether its effect will be beneficial or detrimental is found in the data of the corn oil periods. The digestible crude fiber decreased significantly with the increase in cerelose.

Referring to table 2, the casein used in period 10 was not from the same lot as that used in period 13.[2] Except for ash content, however, the two caseins were closely similar in composition. Casein increased the digestibility of the protein, the ether extract, and the energy and decreased the digestibility of the crude fiber and nitrogen-free extract, in the order of the increas-

[2] Kindly donated by Mead, Johnson & Co.

ing amount of casein in the rations. There was an apparent slight increase in the digestibility of the dry matter in the casein periods, not so marked as previously reported by Harris and Mitchell (1941*b*). There is no direct evidence as to whether the larger amount of casein exceeded or equaled the optimum. The basal ration contained 13.2% protein which was increased to about 20.4% by the addition of the larger amount of casein.

Urea caused extensive increase in the apparent digestibility of the protein, and although the nitrogen balance was not determined, Harris and Mitchell (1041*a*) have shown that sheep could be maintained in nitrogen equilibrium on a low-protein ration with urea supplying 90% of the nitrogen. Urea was apparently well utilized in the experiment here reported, at both levels of intake, being added to a ration already containing 12.9% protein. The tendency toward a lessened digestibility of ether extract and crude fiber can hardly be considered of any importance, since the digestible energy which includes both of these items was fully as high in the urea-supplemented periods as in the basal. Furthermore, Harris and Mitchell (1941*a*) have shown that urea added to a low-protein ration for sheep markedly increased the digestibility of the cellulose.

Periods 15 and 12 which were supplemented with corn oil (34 grams and 68 grams per day respectively) contained 6.4% and 9.8% ether extract while the basal ration contained 2.8%. The maximum amount of corn oil fed was arbitrarily chosen as that which would furnish about the same gross energy as was supplied by the larger quantity of casein fed in the study of this constituent. The addition of highly digestible corn oil would naturally increase the percentage digestibility of the energy of the entire ration provided its effect was merely additive, and since the energy intake was considerably different in the two corn oil periods and the corresponding basal period, no direct comparison is possible. It may be pointed out, however, that the addition of the 34 grams of corn oil in period 15 containing 319 Calories of gross energy increased the digestible energy by 344 Calories (table 4). In the case of crude protein and crude fiber it is possible to consider the direct effect of fat, for these two nutrients were supplied in identical quantities in periods 9, 12 and 15. The significance of the increase in protein digestibility in period 15 as compared to the basal period is indicated by odds of 33 to 1 while in the case of crude fiber the odds are only 7 to 1. This amount of corn oil (34 gms. daily) increased the digestibility (relatively and absolutely) of every feed constituent. Extensive work by Maynard and coworkers with dairy cows over a period of 15 years and several papers by Forbes and associates working with rats have shown that fat in the ration confers economy of utilization of the energy of the entire diet. Such increase may or may not involve greater digestibility but the increase in apparent

digestibility of protein and of energy in this investigation with sheep at least constitutes further evidence that dietary fat is critically important.

When the amount of corn oil was doubled, however (period 12), all of the digestion coefficients except that for ether extract, were reduced to values below those obtained in the basal period, clearly showing that this amount of fat is above the optimum for sheep. In fact the addition of the second 34 grams of corn oil (319 Calories of gross energy) increased the digestible energy of the ration by only 83 Calories. The digestibility coeffi-

TABLE 4. GRAMS OF CONSTITUENTS DIGESTED

Period No.	Supplement	No. of sheep	Dry matter	Crude protein	Ether extract	Crude fiber	N-free extract	Lignin	Energy
			gm.	gm.	m.	gm.	gm.	gm.	Cal.
1	Oat straw (max.)	5	657.0	73.0	17.5	92.9	456.5	−1.2	2911
4	Oat straw (½ max.)	5	634.2	74.6	17.7	75.1	449.4	2.4	2802
7	Basal	5	618.1	77.6	18.7	56.5	448.0	0.9	2749
2	Starch (max.)	—	—	—	—	—	—	—	—
5	Starch (½ max.)	4	637.3	77.2	15.9	60.1	465.5	1.7	2817
8	Basal	4	585.9	80.5	15.6	65.0	405.0	−1.8	2587
3	Cerelose (max.)	4	700.1	74.6	15.0	56.3	535.0	1.2	2988
6	Cerelose (½ max.)	4	658.4	80.1	16.0	63.5	477.7	2.1	2866
9	Basal	4	594.0	81.0	15.9	66.8	410.1	0.0	2617
10	Casein (max.)	5	692.5	177.3	16.7	58.7	418.0	1.0	3214
13	Casein (½ max.)	5	653.7	133.2	16.5	59.6	421.2	0.4	2965
16	Basal	5	607.5	87.1	16.0	63.7	420.1	0.8	2690
11	Urea (max.)	5	602.2	107.5	15.2	62.8	410.0	−1.0	2642
14	Urea (½ max.)	5	599.1	95.4	14.9	66.1	408.3	−0.1	2634
8	Basal	5	585.5	80.5	15.5	64.4	405.1	−2.5	2583
12	Corn oil (max.)	4	628.7	78.7	80.1	54.5	391.7	−1.1	3043
15	Corn oil (½ max.)	4	636.5	84.9	47.4	68.5	418.5	0.2	2960
9	Basal	4	592.7	81.5	16.1	64.6	409.6	0.0	2616

cients of lignin apparently were not affected by the various supplements and were close to zero in all cases, the extreme values being −6.2 and +5.2% (table 3). Twelve values out of 17 did not exceed ±3%. From these and other published data it seems that lignin must be considered indigestible, and that variations in the digestion coefficients, above and below zero are due to experimental error. The irregularity in daily fecal excretion enters into all digestion experiments involving collection periods. An examination of the consecutive daily air-dry weights (unpublished) recorded during 24 10-day collection periods obtained with sheep receiving only roughage (Forbes *et al.*, 1946) shows that if the collection periods had been nine days in length, the average daily feces weights would have differed from the ten

day averages by 1.4% (without regard to sign). The extreme value was 4.5%. A digestion coefficient of approximately 50 percent would be affected by about one-half the amount of the percentage change in the daily weight of feces.

Digestion coefficients, derived by the lignin ratio method as proposed by Ellis, Matrone and Maynard (1946) are given in table 5 along with the values obtained in the conventional manner. Standard errors of the coefficients determined by both methods were computed as well as the standard errors of the differences between them, the latter being interpreted by determining the "P" values (Fisher, 1938, p. 177).

Inspection of table 5 reveals that the standard errors of the digestion coefficients determined by the two methods are of the same general magnitude. Considering that a difference is significant when P is .05 or less, 4 differences out of a possible 90 are significant. In consideration of whether the character of the ration or the individuality of the sheep may be factors influencing the validity of the lignin ratio method, it is observed that the sheep in group 1 in period 4 accounted for 3 of the 4 significant differences (dry matter, crude protein, and energy), the other one occurring in period 6 (crude fiber.) The comparison of the methods thus reveals that 3 out of the 4 significant differences were found with the same group of sheep. In periods 4 and 6, in which one-half the maximum amounts of oat straw and cerelose respectively were fed, the 12 P values were low (.1+ compared to the average of the remaining 78 which was .6+) which suggests that some unknown factor was operative during these periods. It is also notable that in 13 periods, no significant difference was found in the digestion coefficients of any feed constituent when determined by the conventional method and by the lignin ratio method as proposed by Ellis, Matrone, and Maynard. A test of the method applied to the average values obtained from 22 sheep receiving only roughage (Forbes *et al.*, 1946) showed that in no case was there any significant difference in the digestion coefficients obtained by the two methods.

Summary

A study was made of the effect of supplements on the digestibility of a mixed ration for sheep. Using 5 sheep on each treatment, supplements in 2 different quantities were fed, representing crude fiber, ether extract, protein, carbohydrate and urea, respectively. The addition of crude fiber reduced the total amount of protein and ether extract digested, while the most prominent effect of added carbohydrate was to reduce the digestible crude fiber and digestible protein. Casein increased the digestibility of protein, ether extract and energy and decreased the digestibility of the crude fiber and nitro-

TABLE 5. COMPARISON OF CONVENTIONAL AND LIGNIN RATIO METHODS FOR DETERMINATION OF DIGESTION COEFFICIENTS WITH STANDARD ERRORS

Period	Ration	No. of animals	Method of determination	Dry matter, percent	Crude protein, percent	Ether extract, percent	Crude fiber, percent	N-free extract, percent	Energy, percent
1	Oat straw, maximum	5	Conventional	66.9±0.93	62.2±1.75	59.5±1.78	44.8±1.69	78.0±0.60	65.1±0.93
			Lignin	66.4±0.80	61.6±1.55	58.9±1.54	44.0±1.47	77.7±0.53	64.6±0.75
3	Cerelose, maximum	4	Conventional	76.3±0.79	65.4±2.26	60.2±1.89	43.3±1.13	87.7±0.61	73.7±0.93
			Lignin	75.7±0.68	64.4±2.11	59.0±1.64	41.6±1.07	87.4±0.56	72.9±0.78
4	Oat straw, ½ maximum	5	Conventional	71.5±0.46	65.5±0.44	63.0±1.20	47.0±1.28	82.2±0.34	69.4±0.50
			Lignin	70.0±0.34	63.7±0.50	61.0±1.37	44.2±1.06	81.3±0.27	67.8±0.38
5	Starch, ½ maximum	4	Conventional	74.9±0.81	67.1±2.65	63.3±2.79	45.9±1.17	86.0±0.84	73.3±0.93
			Lignin	73.9±0.69	65.8±2.83	62.2±2.51	43.9±0.30	85.5±0.33	72.3±0.78
6	Cerelose, ½ maximum	4	Conventional	77.2±0.63	69.8±1.69	64.0±0.90	48.5±0.83	87.8±0.44	75.0±0.75
			Lignin	75.7±0.72	67.9±1.75	61.7±1.32	45.2±0.83	87.1±0.51	73.4±0.83
7	Basal, (oat straw)	5	Conventional	78.4±0.81	70.6±1.95	69.8±0.63	51.4±1.95	88.2±0.65	76.6±0.90
			Lignin	77.3±0.68	69.1±1.72	68.0±0.51	48.8±3.51	87.6±0.65	75.3±0.79
8	Basal, (starch; urea)	4	Conventional	74.8±0.35	70.2±1.31	62.2±1.43	49.7±0.46	85.3±0.34	72.6±0.53
			Lignin	75.1±0.39	70.6±1.25	62.7±1.18	50.4±0.74	85.5±0.31	72.9±0.50

TABLE 5. (*Continued*)

Period	Ration	No. of animals	Method of determination	Dry matter, percent	Crude protein, percent	Ether extract, percent	Crude fiber, percent	N-free extract, percent	Energy, percent
9	Basal, (cerelose; fat)	5	Conventional	74.6±0.51	69.9±0.85	62.5±1.48	49.7±1.10	84.9±0.45	72.2±0.64
			Lingin	74.8±0.49	70.2±0.86	62.7±1.23	50.2±1.22	85.1±0.42	72.5±0.62
10	Casein, maximum	5	Conventional	77.0±0.37	83.9±0.39	65.7±1.22	44.2±0.86	85.5±0.33	76.4±0.45
			Lignin	76.4±0.35	83.5±0.34	65.1±0.82	42.9±0.47	85.1±0.42	75.8±0.36
11	Urea, maximum	5	Conventional	75.0±0.53	77.1±0.87	60.1±1.42	47.1±0.78	85.4±0.65	72.8±0.61
			Lignin	75.4±0.57	77.4±0.93	60.8±1.52	48.0±0.80	85.7±0.65	73.2±0.68
12	Fat, maximum	4	Conventional	72.8±0.60	67.4±0.38	85.9±0.26	40.7±1.10	81.5±0.75	71.5±0.74
			Lignin	73.1±0.53	67.8±0.54	86.0±0.27	41.3±0.57	81.7±0.72	71.8±0.77
13	Casein, ½ maximum	5	Conventional	77.0±0.40	81.1±0.39	65.0±1.14	44.5±1.00	86.8±0.32	75.7±0.47
			Lignin	76.8±0.07	80.9±0.34	64.6±0.90	44.0±0.62	86.7±0.28	75.4±0.24
14	Urea, ½ maximum	5	Conventional	75.2±0.82	74.6±1.21	59.1±1.51	49.4±0.51	85.5±0.89	72.9±1.06
			Lignin	75.3±0.52	74.7±0.91	59.4±0.96	49.5±0.87	85.5±0.73	73.0±0.72
15	Fat, ½ maximum	4	Conventional	76.2±0.57	72.4±0.74	79.8±0.51	50.9±1.44	86.5±0.54	74.7±0.67
			Lignin	75.7±0.61	71.7±0.84	79.3±0.42	49.7±1.04	86.1±0.61	74.1±0.67
16	Basal, (casein)	5	Conventional	76.2±0.40	74.5±0.94	63.0±2.06	47.5±0.44	87.2±0.37	74.2±0.46
			Lignin	75.7±0.54	74.0±1.07	62.1±2.18	46.4±0.49	86.9±0.47	73.7±0.59

gen-free extract. Urea caused a prominent increase in the digestibility of protein while corn oil in the smaller of the two amounts fed, increased the digestibility of each feed constituent, the larger amount of corn oil having the reverse effect. An application of the "Lignin ratio" method of determining digestibility is presented which shows this procedure to be highly valid.

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UREA AS AN EXTENDER OF PROTEIN WHEN FED TO CATTLE[1]

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DURING the current shortage of protein concentrates, considerable interest has been shown in the possibility of replacing a part of the protein of livestock rations with other forms of nitrogen. This possibility has never been realized to its fullest extent. Urea, $CO(NH_2)_2$, contains 46.6 percent nitrogen, one pound of urea furnishing as much nitrogen as 6.77 pounds of 43 percent protein cottonseed meal. Until recent years experimental evidence was inconclusive as to the ability of ruminants to utilize urea and other simple nitrogen-carrying compounds. Krebs (1937) made a complete review of the literature relative to the feeding of urea, glycocoll and ammonium salts in nitrogen balance experiments. He concluded that values of urea nitrogen in replacing vegetable protein for lactation and growth were not well established, and suggested long time growth experiments. Mitchell and Hamilton (1929) had come to similar conclusions. Hart and co-workers (1939) conducted two such studies with dairy calves and found that for growth a ration in which 43 percent of the nitrogen came from urea was only slightly less valuable than one in which 66 percent of the nitrogen came from casein. Ammonium bicarbonate was also utilized in growth but was less efficient than urea. These simple nitrogen compounds when fed in sufficient amount to balance low-protein rations apparently had no detrimental effect on the animals.

Bartlett and Cotton (1938) fed 21 dairy heifers ranging from 7 to 17 months of age for 142 days on rations that carried normal protein, low protein, and low protein plus 0.127 pound of urea daily. The difference in average daily between the low protein and urea groups was significant whereas that between the urea fed and normal protein groups was not. Work and Henke (1938) also found that heifers fed urea remained thrifty and were intermediate in gain as compared to heifers receiving normal and low-protein rations.

Wegner *et al.* (1941), using the fistula technique at the Wisconsin Station with a 1000-pound Holstein heifer, found that the protein content of the rumen ingesta showed a decided increase when the level of protein in the concentrate fed was increased to 24 percent. When urea was fed with a low-protein ration the rate of conversion of urea nitrogen to protein in the rumen decreased when the protein level of the rumen ingesta exceeded 12

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percent. When the level of protein in the concentrate was increased to more than 18 percent the rate and extent of conversion of added urea nitrogen to protein began to decrease. Urea was utilized efficiently as the only nitrogen supplement when it was fed at such level as to provide a protein equivalent level of 12 percent in the concentrate mix. In a later study (1942) workers at the same station found that nitrogen from urea was used much more efficiently in the presence of starch than when added alone to a timothy hay basal ration.

Harris and Mitchell (1941*a*) in experiments with sheep found that urea added to a low-nitrogen ration improved cellulose digestion and that the nitrogen in urea was 88.88 percent digestible. Nitrogen equilibrium was maintained on 202 mg. of urea nitrogen as well as on 161 mg. of casein nitrogen per kilo of body weight, daily. Sheep were carried for 100 days on a ration in which urea furnished all but 10 percent of the nitrogen required for equilibrium. Urea when fed to satisfy maintenance was not excreted through the skin. The same workers (1941*b*) obtained normal or near normal growth in lambs fed a low-nitrogen basal ration to which sufficient urea was added to make the nitrogen content of the ration equivalent to 11 percent protein. Urea provided 50 percent of the total nitrogen. The nitrogen in a conventional ration containing 5.35 percent protein on a dry basis had a biological value of 82. When urea was added to this ration to give 8, 11, and 15 percent protein equivalents the average biological values were 74, 60, and 44, respectively. Rations containing 3.16 percent urea on a dry basis produced no noticeable toxic effect in a 110-day feeding period.

In later work with lambs, Johnson and others (1942) found that addition of urea to produce up to, but not more than, 12 percent protein equivalent in a ration containing 6 percent natural protein increased nitrogen retention. Above 12 percent, nitrogen retention was improved by addition of protein but not by addition of urea. They expressed the opinion that the nitrogen of urea is not changed to protein rapidly enough to meet the requirement of growing lambs. Supplements of corn molasses inhibited digestibility of cellulose but improved nitrogen retention.

Harris, Work and Henke (1943) in nitrogen balance studies with steers 6 to 8 months old, fed rations of from 12 to 14 percent protein equivalent in which about 90 percent of the protein equivalent was furnished by either urea or soybean oil meal. The apparent digestibility of urea nitrogen was 74 percent and that of soybean oil meal, 78 percent. The true digestibility of the nitrogen from these two sources was 94 percent and the biological values were 34 and 60, respectively. Paunch analysis showed an increase in the true protein content of the ingesta of steers after urea was added to a low nitrogen basal ration. Fingerling *et al.* (1937) likewise found urea could furnish nitrogen needed by growing steers. In a series of nitrogen balance trials

they compared wheat gluten meal with urea when each was added to a low-protein basal ration. From 50 to 61 percent of the urea nitrogen was utilized as compared with 60 to 64 percent utilization of the nitrogen in wheat gluten.

Loosli and McCay (1943) found two months old calves made satisfactory gains in weight and height when urea was added to raise the nitrogen level of a basal ration from 4.4 percent to 16.2 percent protein equivalent. About 73 percent of the nitrogen in the supplemented ration was from urea and had an average biological value of 52. The apparent digestibility of the nitrogen in the ration was about 80 percent. The calves were in negative nitrogen balance on the basal ration but stored from 24 to 36 percent of the nitrogen in the supplemented ration. The apparent digestibility of dry matter and carbohydrate in the basal ration ranged from 57 to 63 percent and from 74 to 80 percent in the basal ration plus urea. Schmidt and Kielsch (1943), however, were unable to show that growing calves used urea nitrogen to an appreciable extent.

William and co-workers (1942) fed urea in four lamb-fattening experiments. When urea nitrogen replaced two-thirds of the nitrogen furnished by a supplement of linseed meal, gains of the lambs nearly equalled those of the lambs receiving straight linseed supplement in a two-year study. When all of the supplement was from urea in four feeding experiments, the results were less satisfactory.

Rupel, Bohstedt and Hart (1943) used mature lactating cows in studying the value of urea in replacing linseed meal in a concentrate mix containing 18 percent protein. The cows fed linseed meal produced slightly more milk but the difference was not significant. Additions of molasses to the grain and urea combination was not found beneficial. These workers felt that urea should not be fed in excess of 1 percent of the dry matter in the ration or 3 percent of the concentrate mix.

Owen, Smith, and Wright (1943) used seven lactating Aryshire cows in a study of the supplementing value of urea when it was used to replace the nitrogen supplied by blood meal in the ration. In five of the seven cows the level of production was maintained when urea replaced blood meal. The urea was fed to the cows at such level that it furnished 25 percent of the total nitrogen intake; apparently 25 percent of the urea passed through the cows unutilized. Willet, Henke and Maruyame (1946) conducted four double change-over trials with producing dairy cows and found that the cows could utilize urea nitrogen to some extent in replacing vegetable protein. The producing efficiency of the cows was not as high when either 19 percent or 36 percent of the total crude protein intake was provided by urea as when all crude protein was of a vegetable source; feeding 25 percent blackstrap molasses in the concentrate mixture had no detrimental effect upon the synthesis of protein in the rumen.

Pearson and Smith (1943*a*, *c*) studied the conversion of urea to protein and found that the presence of starch materially aided this conversion *in vivo*. These workers (1943*b*) suggest that the first change that urea undergoes in the rumen of the dairy cow is its conversion to ammonia and that the change probably occurs within one hour.

Cullison (1944) in making sweet sorghum silage added urea at the rate of 10 pounds per ton to prevent fermentation. In a 78-day feeding period 15 beef cows maintained their weight when fed 35 pounds of urea-treated silage and 5 pounds of Johnson Grass hay per day. Cows fed the same amounts of untreated silage hay lost an average of 47 pounds.

Goss (1943) stated in a review of the subject that much remained to be found out concerning the ability of ruminants to utilize urea nitrogen at various levels of feeding and in various feed combinations. The use of urea for some animals has not been studied except to a limited extent.

Method and Procedure

The value of urea as an extender of protein in feeding beef cattle was studied in different experimental procedures. These studies include (a) metabolism trials, (b) dry-lot fattening experiments, (c) wintering cattle under range conditions, and (d) toxicity tests. Crystalline urea, DuPont "Two-Sixty-Two" feed compound and pelleted feeds containing urea were used in the metabolism studies. In all other feeding trials only the pelleted feeds containing different amounts of urea were used.

In the metabolism studies beef steers were stanchioned in false bottom stalls. Urine was collected by means of a rubber funnel and hose which led into a container beneath the false floor. The feces were allowed to drop in gutter boxes behind the steers, the droppings being picked up at frequent intervals and stored in a metal container. Daily feces and urine collections were measured to the nearest gram or ml. and two percent aliquots were stored in a refrigerator at approximately 0° Centigrade. The urine samples were acidified with sulphuric acid, and thymol was added to both urine and feces to aid in preservation. The steers were fed and watered twice daily during ten-day preliminary feeding periods and ten-day collection periods. Block salt was available at all times except during periods when practically pure urea was fed—at which times urea and salt were fed together. The nitrogen supplements were offered in amounts calculated to provide rations of equal nitrogen content. Refused feed was analyzed and subtracted from that offered to determine dry matter and nutrient intakes. Usual ether extraction procedures were followed in making chemical analyses although it is realized urea is partially soluble in ether.

Standard methods of allotting cattle were followed in dividing the experi-

mental animals for all group-feeding studies which included fattening and wintering trials. In fattening trials the calves were worked to a full-grain feed and the grain was then fed in a self feeder. The daily allowance of the nitrogen supplements was added to the hopper of the self feeder each day; roughages were hand fed once daily. Fresh water, salt and a simple mineral mix of equal parts of steamed bone meal, salt and ground limestone were before the calves at all times.

In the range wintering studies conducted with both yearling heifers and big steers, the animals had free access to winter range, water and salt. They were fed their nitrogen supplement every other day. The heifers were allowed the same simple mineral mix as was fed in the fattening experiments, while the steers that received urea pellets were hand fed steamed bone meal in amounts that gave them the same phosphorus intake as the check lot of steers receiving cottonseed cake. These cattle had no shelter other than that naturally provided on the range.

In the toxicity studies, light weight calves were fed in dry lot to determine whether or not urea in a pelleted feed would be toxic when used to supplement a full feed of hay. Five other steer calves were individually full fed on the urea-containing supplement for fourteen days after no ill effects were observed from feeding the first five calves.

Experimental Results

Metabolism Studies

In the first metabolism study, which was a comparison between different preparations of urea and cottonseed meal as sources of nitrogen to supplement prairie hay, five nitrogen balance trials were carried out with four steers in each trial. The steers were yearling Shorthorns which averaged about 500 pounds in weight. During the first trial the steers were offered prairie hay alone at the rate of 10 pounds per day; during the next four trials they received in addition to the same allowance of hay one of the nitrogen supplements shown in table 1. The supplements were fed in the following order: urea pellet No. 4 (a pelleted urea feed), crystalline urea, cottonseed meal, and DuPont's "Two-Sixty-Two" feed compound. The composition and daily allowance of feeds are given in table 1.

The steers refused approximately 10 percent of the hay allowance when it was fed unsupplemented but refused less than 5 percent when any of the supplements was fed. There were no refusals of supplement. The average protein content of the dry matter eaten by steers receiving the supplemental rations varied from 8.7 to 9.1 percent. Data secured in these trials are shown in table 2.

In the second metabolism study conducted with four yearling Hereford

TABLE 1. DAILY AMOUNT AND CHEMICAL COMPOSITION OF HAY AND SUPPLEMENTS OFFERED YEARLING STEERS IN THE FIRST METABOLISM STUDY

Feed	Daily allowance	Dry matter	Percentage composition of dry matter				
			Protein (N×6.25)	Ether extract	Crude fiber	Nitrogen free extract	Organic matter
	gm.	percent					
Prairie hay	4536	90.2	3.12	2.39	32.26	55.68	93.45
Cottonseed meal	680	91.5	45.04	7.76	10.15	30.97	93.92
Urea pellet No. 4[1]	680	89.3	48.77	7.05	3.97	36.47	96.26
DuPont "Two-Sixty-Two"[2]	96.4	100.0	263.10	—	—	—	97.80
Crystalline urea[2]	89.4	100.0	283.40	—	—	—	—

[1] Practically all of the nitrogen in urea pellet No. 4 was provided by urea. The pellets were composed of hominy feed with 10 percent of blackstrap molasses and sufficient urea to give a total crude protein equivalent of 43.5 percent on an air-dry basis. They were manufactured through the courtesy of Nutrena Mills, Inc.

[2] DuPont "Two-Sixty-Two" feed compound is a commercial preparation of urea with small amounts of conditioning agents added to improve mixing qualities. This product and the crystalline urea were obtained through the courtesy of E. I. du Pont de Nemours and Co., Inc.

steers averaging about 570 pounds in weight, cottonseed meal was compared with pelleted protein supplements containing different amounts of urea. These pelleted supplements designated in the text and tables as urea pellet No. 1, 2, and 3 contained urea in such amounts as to furnish approximately 25, 50 and 75 percent, respectively, of the total supplemental nitrogen, the rest of the nitrogen in the supplement coming from cottonseed meal, hominy feed and molasses. All of the pellets contained 10 percent blackstrap molasses,

TABLE 2. AVERAGE APPARENT DIGESTIBILITY OF NUTRIENTS AND AMOUNT OF NITROGEN STORED BY STEERS RECEIVING RATIONS OF PRAIRIE HAY AND DIFFERENT NITROGEN SUPPLEMENTS IN THE FIRST METABOLISM STUDY

Supplement fed with prairie hay	Apparent digestibility of nutrients in ration					Daily nitrogen intake	Daily nitrogen storage
	Protein (N×6.25)	Ether extract	Crude fiber	N-free extract	Organic matter		
	percent	percent	percent	percent	percent	gm.	gm.
None	−9.8	15.2	55.6	50.4	49.3	18.1	−14.4
Cottonseed meal	48.2	47.9	65.2	54.0	56.7	64.1	6.5
Urea pellets No. 4	57.5	39.0	61.5	54.6	56.4	66.3	3.4
Du Pont "Two-Sixty-Two"	61.3	19.1	53.3	47.3	46.7	60.4	3.8
Crystalline urea	60.0	21.9	56.4	48.6	48.2	59.6	−5.3
Difference[1] in mean required for							
5% Point	4.3	5.6	4.6	2.9	3.0	—	3.2
1% Point	5.9	7.7	6.4	4.0	4.2	—	4.4

[1] Calculated from the analysis of variance method of Snedecor (1938).

while in addition, pellet No. 1 contained 4 percent Du Pont's "Two-Sixty-Two," feed compound, 75 percent cottonseed meal and 11 percent hominy feed. Pellet No. 2 contained twice as much "Two-Sixty-Two," 50 percent cottonseed meal and 32 percent hominy feed, while pellet No. 3 contained 12 percent, 25 percent and 53 percent, respectively, of these ingredients. The composition and daily allowance of feeds used in this trial are given in table 3.

TABLE 3. DAILY AMOUNT AND CHEMICAL COMPOSITION OF HAY AND SUPPLEMENTS OFFERED YEARLING STEERS IN THE SECOND METABOLISM STUDY

Feed[1]	Daily allowance	Dry matter	Percentage composition of dry matter				
			Protein (N×6.25)	Ether extract	Crude fiber	N-free extract	Organic matter
	gm.	*percent*					
Prairie hay	4536	92.2	3.29	2.28	33.61	53.38	92.56
Cottonseed meal	1050	91.6	43.80	6.68	10.17	32.97	93.62
Urea pellet, No. 1	978	89.6	46.60	6.65	8.94	30.51	92.70
Urea pellet, No. 2	884	89.0	50.58	7.05	7.37	28.67	93.67
Urea pellet, No. 3	910	88.7	49.14	7.37	5.25	33.21	94.97

[1] The urea pellets were manufactured through the courtesy of Nutrena Mills, Inc.

The basal ration of hay was fed at the same time to all steers in the second trial and the four supplemented rations were fed to each of the steers in rotation. Hay refusals were about the same as in the first metabolism study when the hay was fed alone. There were no refusals of hay when cottonseed meal was fed as a supplement, and only occasional small refusals when the urea pellets were fed. There were no refusals of supplements. The average protein content of the dry matter eaten by the steers when the supplemented rations were fed varied from 10.66 to 10.83 percent.

The data secured in these trials are shown in table 4.

In a third metabolism trial conducted with three long-yearling Hereford steers averaging about 650 pounds in weight cottonseed meal was compared with urea pellets No. 1 and No. 2 in a fattening ration. The ration was the same as that used in the second group-feeding fattening trial discussed later in this paper. The constituents of the ration and their composition are shown in table 5.

The steers ate the fattening rations readily and only occasionally refused a small amount of feed. The average protein content of the dry matter eaten when rations A, B and C were fed was 12.24, 12.53 and 12.37 percent, respectively. The data secured in these trials are shown in table 6.

TABLE 4. AVERAGE APPARENT DIGESTIBILITY OF NUTRIENTS AND AMOUNT OF NITROGEN STORED BY STEERS RECEIVING RATIONS OF PRAIRIE HAY AND DIFFERENT NITROGEN SUPPLEMENTS IN THE SECOND METABOLISM STUDY

Supplement[1] fed with prairie hay	Apparent digestibility of nutrients in ration					Daily nitrogen intake	Daily nitrogen storage
	Protein (N×6.25)	Ether extract	Crude fiber	N-Free extract	Organic matter		
	percent	*percent*	*percent*	*percent*	*percent*	*gm.*	*gm.*
None	−0.9	36.7	59.8	48.9	50.9	16.7	10.5
Cottonseed meal	58.0	57.3	62.6	55.9	58.3	87.8	18.7
Urea pellet No. 1	60.5	58.7	62.9	55.6	58.5	87.2	19.7
Urea pellet No. 2	62.4	54.5	61.7	54.0	57.5	85.8	17.5
Urea pellet No. 3	64.5	54.3	60.8	54.6	57.6	83.8	10.7
Differences in mean required for, 1% point	3.3	4.2	6.7	4.0	4.4	—	5.0
5% point	4.5	5.8	9.2	5.5	6.0	—	6.9

[1] The urea pellets were manufactured through the courtesy of Nutrena Mills, Inc.

TABLE 5. DAILY AMOUNT AND CHEMICAL COMPOSITION OF THE FEEDS USED IN FATTENING RATIONS GIVEN YEARLING STEERS IN THE THIRD METABOLISM STUDY

Feed[1]	Daily allowance in			Dry matter	Percentage composition of dry matter				
	Ration A	Ration B	Ration C		Protein (N×6.25)	Ether extract	Crude fiber	N-free extract	Organic matter
	gm.	*gm.*	*gm.*	*percent*					
Prairie Hay	964	964	964	93.56	4.64	21.3	34.86	51.03	92.67
Ground corn	5454	5454	5454	88.82	8.73	5.07	2.13	82.61	98.54
Cottonseed meal	795	—	—	91.21	45.24	6.91	10.01	31.95	94.11
Urea pellet No. 1	—	794	—	90.68	45.97	6.18	7.92	33.61	93.68
Urea pellet No. 2				89.37	47.00	5.09	5.66	37.28	95.03

[1] Urea pellets No. 1 and No. 2 were prepared from the same formula and by the same company as described in tables 3 and 4.

Fattening Studies

Two lots of five yearling cattle each were used in the first fattening experiment to compare cottonseed meal with urea pellet No. 4. This pellet, which is described in the footnote of table 1, had practically all of its nitrogen in the form of urea. The urea pellets and cottonseed meal were fed as supplements in a fattening ration of corn, wheat, oats and prairie hay. The grain was ground and fed in a self feeder and the respective supplements added to the hopper daily. Although it was originally intended to feed the same

TABLE 6. AVERAGE APPARENT DIGESTIBILITY OF NUTRIENTS AND AMOUNT OF NITROGEN STORED BY STEERS RECEIVING FATTENING RATIONS IN THE THIRD METABOLISM STUDY

Supplement fed with prairie hay and corn	Ration	Apparent digestibility of nutrients in rations					T.D.N. of rations	Daily nitrogen intake	Daily nitrogen storage
		Protein (N×6.25)	Ether extract	Crude fiber	N-Free extract	Organic matter			
Cottonseed meal	A	56.9	69.8	40.4	74.5	69.4	64.3	126.7	30.3
Urea pellet No. 1	B	63.4	77.6	47.7	77.2	73.3	68.3	123.6	40.7
Urea pellet No. 2	C	63.1	79.3	47.9	76.1	72.5	67.3	126.7	36.7
Differences in mean required for:									
5% point		7.4	19.1	15.1	2.8	2.5	—	—	19.8
1% point		10.4	26.4	20.8	3.9	3.6	—	—	27.4

amount of each supplement daily, the steers refused to eat all of their allowance of the urea pellets. The results of the experiment are given in table 7.

Since urea pellets containing such a high proportion of urea appeared to be unpalatable, two more fattening trials were carried out with calves to compare urea pellets No. 1 and 2 with cottonseed meal as supplements in a fat-

TABLE 7. DATA SECURED WITH FATTENING YEARLING CATTLE FED SUPPLEMENTS OF COTTONSEED MEAL AND UREA PELLET NO. 4 SUMMER 1944; 160 DAYS, 5 ANIMALS PER LOT

Items compared	Lot No. and ration	
	Lot I, cottonseed meal	Lot II, urea pellet No. 4
Av. weights per steer, lbs.		
Initial wt.	545	535
Final wt.	870	794
Daily gain	2.03	1.62
Av. daily rations, lbs.		
Corn	5.05	4.97
Wheat	8.12	7.60
Oats	1.12	.99
Cottonseed meal	1.97	—
Urea pellet No. 4	—	1.64
Prairie hay	2.51	2.21
Feed per cwt. gain, lbs.		
Corn	248.60	307.2
Wheat	399.80	496.6
Oats	55.20	61.1
Cottonseed meal	96.70	—
Urea pellet No. 4	—	101.3
Prairie hay	123.50	136.6

tening ration of corn and prairie hay. These pellets, as previously described in the footnote of table 1 had approximtately 25 percent and 50 percent of their nitrogen, respectively, in the form of urea. The results of these fattening trials with calves are given in table 8.

TABLE 8. DATA SECURED WITH FATTENING CALVES FED SUPPLEMENTS OF COTTONSEED MEAL AND UREA PELLETS NO. 1 AND NO. 2. WINTER 1944–1945; 153 DAYS; WINTER 1945–1946; 167 DAYS; 10 ANIMALS PER LOT IN EACH YEAR

Items compared	Lot No., ration and year					
	Lot I, Cottonseed meal		Lot II, Urea pellet No. 1		Lot III, Urea pellet No. 2	
	1944–45	1945–46[1]	1944–45	1945–46	1944–45	1945–46
Av. wt. per calf, lbs.						
Initial wt.	434	410	438	398	438	399
Final wt.	711	718	737	693	741	669
Daily gain	1.81	1.85	1.95	1.77	1.98	1.61
Av. daily ration, lbs.						
Corn	11.7	10.1	12.5	9.7	12.1	9.5
Cottonseed meal	1.8	2.0	—	—	—	—
Urea pellet No. 1	—	—	1.8	1.9	—	—
Urea pellet No. 2	—	—	—	—	1.7	1.6
Prairie hay	2.1	1.8	2.1	1.8	2.1	1.8
Feed required per cwt. gain, lbs.						
Corn	649	545	639	549	610	589
Cottonseed meal	100	106	—	—	—	—
Urea pellet No. 1	—	—	91	109	—	—
Urea pellet No. 2	—	—	—	—	87	99
Prairie hay	117	98	107	104	107	109

[1] It was necessary to remove a lightweight calf early in the experiment, consequently the data for this lot are based on nine steers.

Wintering Studies

The results secured during two years when yearling Hereford heifers were wintered on the range with urea pellet No. 1 and cottonseed cake as supplements are given in table 9.

Heavy steers were wintered one year under range conditions in a comparison between cottonseed cake and urea pellet No. 1 as supplements. The results are given in table 10.

Toxicity Studies

The five plain-bred steer calves chosen for the preliminary study of the toxicity of urea were individually offered urea pellet No. 1, which contained 4 percent of DuPont's "Two-Sixty-Two" at different levels of feeding. The

TABLE 9. DATA SECURED IN WINTERING YEARLING HEIFERS ON DRY GRASS WITH SUPPLEMENTS OF COTTONSEED MEAL AND UREA PELLET NO. 1

Items compared	Lot No., supplement and year			
	Not No. I, cottonseed cake		Lot No. II, urea pellet No. 1	
	1944–45	1945–46	1944–45	1945–46
Start of trial	Nov. 14	Nov. 6	Nov. 14	Nov. 6
No. of days	143	148	143	148
No. head per lot	8	10	7	10
Av. wt. per heifer, lbs.				
Initial	707	638	700	638
Final	745	681	740	686
Daily gain	.26	.29	.28	.33
Av. daily ration, lbs.				
Dry grass	free choice	free choice	free choice	free choice
Cottonseed cake	2.35	2.34	—	—
Urea pellet No. 1	—	—	2.35	2.34

rates at which the pellets were fed daily to four of the calves were 0.5 lb., 0.75 lb., 1.0 lb. and 1.5 lbs. per hundred pounds live weight; the fifth steer calf was offered a full feed of the pellets. All of the calves were full fed prairie hay. When none of the calves showed ill effects from the urea pellets, five similar steers were individually fed full on the pellets with prairie hay *ad*

TABLE 10. DATA SECURED IN WINTERING 2-YEAR OLD STEERS ON DRY GRASS WITH SUPPLEMENTS OF COTTONSEED CAKE AND UREA PELLET NO. 1. NOVEMBER 6, 1945 TO MARCH 12, 1946; 126 DAYS; 24 STEERS PER LOT

Items compared	Lot No. and supplement	
	Lot No. I, cottonseed cake	Lot No. II, urea pellet No. 1
Av. wt. per steer, lbs.		
Initial wt.	854	854
Final wt.	887	860
Daily gain	.26	.05
Av. daily ration, lbs.		
Dry grass	free choice	free choice
Cottonseed cake	3.02	—
Urea pellet No. 1	—	3.02
Bonemeal	—	.05
Salt	.07	.08
Appraised price per cwt. (March 12)	$16.00	$16.00

lib. The five calves had an average body weight of 455 pounds at the beginning of the 14-day feeding period and consumed slightly over 10 pounds of the pellets daily. They weighed an average of 469 pounds at the close of the period, having gained an average of 1.0 lb. daily. They had consumed .37 lb. of urea daily. This amount of urea was equivalent to about 2.2 percent of the dry matter eaten and is within the limit of safety that has been suggested by Hart *et al.* (1939) and by Work and coworkers (1943).

The latter five steer calves were then placed on a full feed of a standard fattening ration for 62 days to measure their response to feed. At the end of the feeding period they were slaughtered and a gross and histological examination of their kidneys made for possible urea damage. The five steers consumed an average of 10.4 lbs. ground wheat, 0.5 lbs. oats, 1.5 lbs. cottonseed meal, 0.6 lb. prairie hay, 0.8 lb. alfalfa hay and 11.4 lbs. of sorgo silage daily during the fattening period and made an average daily gain of 3.1 pounds. The kidneys of all five steers appeared normal upon gross examination and histological sectioning.[3]

Discussion

Digestion Trials. It is a general observation that the addition of protein supplements to a low-protein ration promotes feed consumption. In the first metabolism trial of the present experiments, the addition of urea produced such a response, the average daily increases in the hay consumption when DuPont's "Two-Sixty-Two" and crystalline urea were fed being 400 and 308 grams, respectively. This effect in itself might be interpreted as indirect evidence of the enhancement in nutritive value of low-protein hay by the addition of urea, although there was no corresponding increase in the digestibility of ration nutrients other than nitrogen. The addition of urea in combination with carbohydrates, however, as when urea pellet No. 4 was fed, was accompanied by an increase in digestiiblity of ration nutrients similar to that produced by cottonseed meal; organic matter digestibility increased from 49.3 percent to 56.4 percent and crude fiber digestibility from 55.6 percent to 61.5 percent. Apparently the combination of carbohydrates supplied by hominy feed and molasses with approximately 12 percent urea in pellet No. 4 was favorable for the activity of rumen organisms concerned with the fermentation of crude fiber.

In the second metabolism trial, as in the first, the digestibility of corresponding nutrients was higher in the cottonseed meal and urea pellet rations than in the basal hay ration. Differences in crude fiber digestibility attributable to the addition of supplement, however, were not significant. Except for the apparent digestibility of protein, which increased with increasing

[3] The authors are indebted to Dr. Lewis H. Moe of the Veterinary Department for the examination of the kidneys.

amounts of urea in the supplement, there were no significant differences in digestibility between the cottonseed meal ration and any one of the urea supplemented rations.

In the third metabolism trial with a fattening ration of high carbohydrate content, higher digestibility values were obtained with urea pellets No. 1 and 2 as supplements than with cottonseed meal. In only a few instances were these differences statistically significant.

It appears from these results that digestion trials alone are not sufficiently critical to reveal any marked change in nutritive value of rations when urea in combination with carbohydrate feeds is used to replace varying amounts of a natural protein supplement such as cottonseed meal.

Nitrogen Storage. Because of feed (hay) refusals and small but measurable variations in the composition of hay, exact quantitative treatment of the results obtained in the nitrogen balance studies is not permissible. From the combined results, however, certain facts appear evident as, for example, the greater apparent digestibility of urea nitrogen than cottonseed meal nitrogen when these materials were fed as supplements in a ration of low protein hay. In the first metabolism trial, apparently only a small portion of the supplemental nitrogen supplied as crystalline urea was converted in the rumen to protein requiring further enzymic digestion for absorption. The remaining portion for the most part, was absorbed, possibly as ammonia, and eliminated through the kidneys.

In the second metabolism trial pellets in which urea supplied 25 percent and 50 percent of the supplemental nitrogen induced about the same nitrogen storage as cottonseed meal. When further substitution was made with urea in amounts to provide 75 percent of the supplemental nitrogen storage, values were decreased from 18.7 grams to 10.7 grams, daily. In the third metabolism trial when fattening rations were fed the nitrogen storage values exceeded 30 grams daily. Here, again, pellets that supplied urea at the 25 and 50 percent level supplemental nitrogen again proved to be equal to cottonseed meal.

Fattening Trials. In the first fattening trial (table 7) the urea pellets No. 4 proved unpalatable and unsatisfactory in their performance. These pellets which contained little supplemental nitrogen except that provided by urea were not used in further fattening trials. Urea pellet No. 3 has not been used in fattening trials as it gave unsatisfactory results when compared to cottonseed meal or urea pellets Nos. 1 and 2 in metabolism trials.

The results of the second and third fattening trials, given in table 8, indicate that urea pellet No. 1 was consumed with relish in both trials and that it can be satisfactorily substituted for straight cottonseed meal in commercial fattening operations. In both of these trials the steers receiving the urea

pellet No. 2 tired of their supplement and refused a large proportion of it in the final phases of the experiment. Evidently the formula used was unsatisfactory for long-time commercial feeding operations although the steers receiving the feed in 1944-45 made satisfactory gains for the entire experiment.

Wintering Trials. Yearling heifers have been wintered as satisfactorily on urea pellet No. 1 as on cottonseed cake when both were fed under range conditions during two winters. These results are given in table 9. No difference was noted in the apparent thrift of the heifers fed the two supplements.

The results given in table 10 show that mature steers did not winter as well when urea pellet No. 1 was fed as when cottonseed meal was the supplement. The supplement was fed on alternate days as was done in the above trial with heifers. Work in progress at this station indicates that urea pellet No. 1, when fed in large amounts every other day, does not result in as efficient nitrogen storage as when fed twice daily. On the other hand, these variations in frequency of feeding cottonseed meal, have not influenced the storage of nitrogen.

Summary

Crystalline urea, DuPont's "Two-Sixty-Two" feed compound and pelleted feeds containing urea were used in a series of digestion trials and feeding experiments to determine the value of urea in extending the available supply of protein supplement for beef cattle. The pelleted feeds contained 10 percent blackstrap molasses, and varying amounts of hominy feed, cottonseed meal, and either crystalline urea or DuPont's "Two-Sixty-Two."

These supplements in which approximately 25 percent, 50 percent, 75 percent, or nearly 100 percent of the supplemental nitrogen has been furnished by urea, were fed with a basal ration of low grade prairie hay to yearling and two-year-old steers in metabolism stalls. When fed under such conditions, the pellets which did not carry more than 50% of their total supply of nitrogen from urea and the remainder largely from cottonseed meal, were similar to straight cottonseed meal in promoting nitrogen storage. Urea alone was a poor supplement to prairie hay.

Pellets containing approximately 25 percent of their nitrogen as urea proved satisfactory as a source of supplemental nitrogen in two dry lot studies with fattening calves. Pellets containing 50 percent of their nitrogen as urea were a satisfactory supplement in the early phases of a fattening period, but proved unpalatable in the later phases.

In two experiments, pellets containing approximately 25 percent of their nitrogen as urea have given as satisfactory performance as cottonseed meal when fed to yearling heifers on the range. In one test the pellets did not

prove as satisfactory as cottonseed meal in wintering heavy steers under range conditions.

No results indicating toxic effects of urea were obtained in these studies although urea was fed as a source of nitrogen at relatively high levels.

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THE REPEATABILITY OF THE YEARLY PRODUCTION OF RANGE COWS[1]

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A KNOWLEDGE of the repeatability of production records is important in breeding operations and cattle improvement. The success of selecting breeding females on the basis of production records depends on the correlation of observed and future production. In addition, an estimate of the correlation of yearly records is invaluable in assigning animals to experimental groups and in reducing the statistical error in group comparisons. The reduction of error is particularly important in comparing essentially small lots such as sire groups.

In determining the effect of sires on weaning weight of calves, it was found (unpublished data) that the variance among calves was so large that differences due to sires was obscured entirely or rendered of doubtful significance. It became evident that if any progress was to be made in selecting sires on the basis of performance on the range, the separable variance contributed by various factors would have to be segregated and controlled statistically in order to evaluate the influence of sires. The inherent influence of the productive capacity of different cows on the total variance observed in calves is the fourth factor which we have found that can be determined and controlled statistically. The influence of sex of calf, weaning age of calf and age of dam have been reported previously (Koger and Knox, 1945*a*; Koger and Knox, 1945*b*; and Knox and Koger, 1945). Earlier reports concerning the influence of the productive capacity of the dam on range calves are not known.

Methods

The records used in this study were weaning data on calves produced at the experimental ranch of the New Mexico Agricultural Experiment Station from 1935 through 1945. They include only records of calves from cows that produced their first calf at three years of age and yearly thereafter as long as their calf records were included. There were 77 cows which had records complete for 5 years, 96 for four years, 121 for three years, and 142 for two years.

Weaning weights were corrected to a standard weaning age of 205 days (Koger and Knox, 1945*b*) and a correction was made for sex of calf by adding

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30 pounds to the weight of heifers (Koger and Knox 1945a). The age of dams (Knox and Koger, 1945) and the varying amounts of feed produced in different years also affect the weight of calves but these factors were controlled statistically rather than by the use of further correction factors. Cows that came into production during different years were treated as separate groups. This largely removed the influence of the age of dam and of years in the correlation and regression studies since the corresponding records of each cow used in calculating covariance were made under similar conditions. The same effect was accomplished in the analysis of variance by removing the sums of squares due to age of dam, which was coincident with different years.

No corrections were made for the grade of calf which was determined by averaging the scores of three judges. The original scores were letter grades

TABLE 1. CORRELATION AND REGRESSION COEFFICIENTS FOR VARIOUS COMBINATIONS OF PRODUCTION RECORDS OF RANGE COWS

Comparison made	Degrees of freedom	Correlation coefficient*		Regression coefficient	
		Weight	Grade	Weight	Grade
One year's calf with next	909	.49	.25	.50	.28
First year's calf and:					
1. second	133	.66	.24	.76	.31
2. average of second and third	113	.53	.39	.65	.34
3. average of second, third, and fourth	89	.51	.40	.43	.32
4. average of second, third, fourth, and fifth	71	.53	.42	.32	.24
Average of first two calves and:					
1. third	113	.54	.46	.69	.44
2. average of third and fourth	89	.55	.60	.60	.50
3. average of third, fourth, and fifth	71	.59	.69	.52	.47

* All correlation coefficients are highly significant, having a probability value of less than 1 percent.

ranging from A plus to C as the lowest grade recorded. Each score was assigned a numerical value, A plus being given a value of 130 and each successive lower grade receiving a score of 10 points less. Thus, an average or B plus calf received a score of 100, a poor calf grading C, a score of 60, etc.

Correlation and regression coefficients were computed for various combinations of records and are shown in table 1. The analysis of variance of calves from cows with five consecutive records is presented in table 2. The values shown in the tables were derived by pooling the sums of squares from the different groups.

TABLE 2. ANALYSES OF VARIANCE OF WEANING WEIGHTS AND GRADES OF CALVES FROM COWS WITH FIVE CONSECUTIVE RECORDS

Source of variance	Degrees of freedom	Mean squares	
		Weaning weight	Grade
Within groups of cows	380	2,181	116
Age of dams within groups	20	22,162**	141*
Remainder	360	1,098	115
Cows within groups	72	3,335**	266**
Remainder	288	540	77

* Probability value less than 5 percent.
** Probability value less than 1 percent.

Results

A highly significant positive correlation existed between early and subsequent records in every comparison made. This was true for both weight and grade of calf although there were important differences in magnitude of correlation coefficients and in the effects of averaging more than one year's record in comparisons.

Weaning Weight

The average correlation of one year's calf weight with the next for all ages of dams was .49 while that of the first year's calf weight with the second was higher, the correlation coefficient being .66. When the average of 2 or more records was compared with the first calf weight, the coefficients varied from .51 to .53. The inclusion of the second record in the initial observation did not materially increase the correlation with subsequent production. The correlation between the average of the first two records and various numbers of subsequent records varied from .54 to .59.

Analysis of variance (table 2) of calf weights from cows with five consecutive records showed that after the variance due to ages was removed, difference in cows accounted for 51 percent of the remaining variance.

Grade of Calf

The correlation of adjacent calf grades was lower than that for weaning weights. The correlation coefficient for first and second calf grades was .24, being similar to other adjacent records, while varying from .39 to .42 when the first calf grade was compared with the average of more than one subsequent grade.

The inclusion of a second grade in the first observation resulted in a marked increase in correlation with subsequent grades. The correlation

coefficients between the average of the first two grades with the various numbers of later calf grades varied from .46 to .69 (table 1). Analysis of variance showed that after the influence of age of dam was removed, differences in cows accounted for approximately 33 percent of the variance in calf grades.

Discussion

The weaning weights of range calves are undoubtedly largely determined by the amount of milk supplied by the dam; thus, the weaning weights of calves should give a fair index of the milk production of different cows. Because of the variation in growth response of calves, the repeatability of calf weights might be expected to be lower than that of milk production.

The repeatability of milk production records of dairy cows has been reported by most authors (Berry, 1945; Dickerson, 1940) to be lower than that of calf weight reported in this paper. However, with the conditions under which these cows were kept, a correlation of yearly production would be expected to be higher than that reported for dairy cattle. All cows in an age group were subjected to much the same conditions. They were together in the same pasture until their first calf was weaned, and many remained together until the second calf was produced. Thereafter, they were scattered in different pastures which provided much the same amount and quality of feed. All cows calved during March, April, and May and the calves were weaned at the same time in the fall. Thus, varinance due to different intervals between calving, different seasons of production, etc. were mostly avoided. In addition, the production of range cows is affected less by such factors as mastitis, loss of quarters, going off feed, and ailments of various kinds. Also, the management mentioned above likely accounts for the failure of the inclusion of a second record to increase appreciably the accuracy of predicting future production. The first calves were from the same sire and from dams that had received identical treatment. Inclusion of a second calf weight introduced records that were not made under the same conditions. This also explains the fact that weights of calves from cows at 3 and 4 years of age were more highly correlated than adjacent records made at other ages.

It was to be expected that correlation of adjacent calf grades would be less than that of weight, and that cows would account for a smaller percent of the variance. The cow contributed genetic factors for rate of growth and in addition provided a relatively uniform amount of milk for each calf. From the standpoint of weight of calf weaned, the latter undoubtedly is of greater importance. In the case of grade, the cow contributed genetic factors for conformation of calf but the amount of milk produced did not materially affect the grade. All cows produced enough milk to raise a calf with enough

condition to grade almost as high as its conformation would justify. This is known from experience and is shown by the fact that age of dam did not account for a large percentage of the variance in grade of calves. The influence of the sire on the grade of calf was equal to that of the dam, while the influence of sire on weight was less than that of dam (unpublished data). This accounts for the fact that the inclusion of a second calf record increased the accuracy of predicting future grades.

Although the correlations found in this study are higher than might be expected under many conditions, they indicate that records are useful in selecting range cows for a high level of production. It is of importance that in this study, much of the covariance was derived from the unusually good and poor producers occurring in a group. A first calf heifer that weaned a decidedly substandard calf, barring accidents such as crippling, was never a heavy producer in later years. The future ranking of animals with first records nearer to the average was less certain.

The importance of accounting for the influence of dams in evaluating the get of a sire will be reported separately.

Summary

The repeatability of the yearly weaning weights and grades of calves from range cows was investigated by determining the correlations between various combinations of records and by analysis of variance of grades and of weights of calves from cows with five consecutive records.

The average correlation of the weight of all adjacent calves was .49. The correlation of the weight of first calf with that of the second was .66. When the first record was compared with the average of various members of subsequent records, the correlation coefficients varied from .51 to .53. When the average of the first two records was compared with various combinations of subsequent records, the coefficients varied from .54 to .59, being only slightly higher than when one record was included in the initial observation. Analysis of variance showed that after the influence of age of dam was removed, the permanent differences in cows amounted to 51 percent of the remaining variance.

The correlation of adjacent grades of calves was .24; that of the first grade and various combinations of subsequent records varied from .25 to .42. The inclusion of a second record in the initial observation almost doubled the magnitude of correlation with subsequent calf grades. Analysis of variance showed that after variance due to age of dam and different years was removed, differences in cows accounted for 33 per cent of the remaining variance.

These data indicate that considerable progress can be made in selecting

breeding range cows on the basis of the first calf record, and that differences in the inherent producing abilities of cows frequently may need to be considered in making group comparisons.

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FACTORS AFFECTING THE ESTIMATION OF CONCENTRATION OF SPERM IN RAM'S SEMEN BY THE PHOTOELECTROMETRIC METHOD

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PHOTOELECTROMETRIC measure of the turbidity in diluted semen samples has been used as an estimate of the concentration of sperm in semen because it was more rapid and less tedious than the use of a hemacytometer. Comstock and Green (1939) and Comstock *et al.* (1943) described a photoelectrometric method for estimating concentration of sperm in rams' semen at a dilution of 1:188 in 1 percent sodium citrate. They claimed accuracy for the colorimeter equal to the "mean of two or three counts." Henle and Zittle (1942), using a Klett-Sommerson colorimeter to estimate concentration of bovine sperm, found that counts and turbidimetry agreed within 10 percent. Jones and Lamoreux (1942), using a method based on that of Comstock and Green, found a dilution of 1:800 in Ringer's solution appropriate for fowl semen. Salisbury *et al.* (1943), using bull semen at a dilution of 1:11 in 0.067 M. sodium citrate, concluded that the accuracy of their colorimeter was about the same as that for the hemacytometer. Blum (1945) described the photoelectrometric principle as applied to making estimates of red blood cell concentration.

The object of this study was to identify and evaluate various factors contributing to the accuracy of estimating concentration of sperm in ram's semen and to devise methods which would give the most accurate results.

Materials

Semen samples were obtained from Rambouillet, Columbia and Targhee rams. Single ejaculates were collected by the method outlined by Terrill (1937) from ewes in diestrus. Pooled ejaculates were used for some phases of the study. Two Spencer Brightline hemacytometers which agreed in duplicate sampling were used for the counts. A Klett-Sommerson photoelectric colorimeter, with a logarithmic scale, matched photoelectric cells and compensated circuit, was used for measuring turbidity. A blue filter, furnished for turbidimetry with the instrument, was used. Readings were made using colorimeter tubes of matched optical qualities. All counts in 1945 were made by one worker and in 1946 by another worker.

[1] The authors are particularly indebted to Dr. C. E. Terrill for assistance and advice on various aspects of the project, and to Dr. L. N. Hazel for assistance in compiling the 1945 data.

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Methods and Results

Statistical Methods

The statistical methods and symbols employed in this paper follow the basic principles of regression and covariance analysis as given in Snedecor (1946).

Both hemacytometer counts and colorimeter readings are subject to sources of error. The sources of error in counts are: dilution, heterogeneity of semen, errors in counting, and distributional errors (Poisson). Those in readings are: dilution, heterogeneity of semen, errors in reading, turbidity due to elements other than spermatozoa (debris) and distributional errors (Poisson). Errors due to dilution and heterogeneity of semen have been eliminated in the later samples by making both count and reading from the same diluted sample. The volume of sample measured in the colorimeter is roughly 1 ml. which is 50,000 times that counted in the hemacytometer. The theoretical variance of such a sample is roughly 0.04 percent of the mean, compared to 2 to 10 percent for the hemacytometer, and so may be disregarded. Errors of workers in making counts and readings were found to be negligible. There remain two unaccounted sources of error, debris in the colorimeter and Poisson variance in the hemacytometer.

The Poisson variance of counts is under statistical control since it is restricted to known limits, and the mean is unbiased for large numbers. On the other hand, the function of debris in increasing turbidity is biased and unknown as to variability. Such a condition is not ideal for regression (Eisenhart, 1939), but the correlations in these data are high enough that covariance accounts for over 80 percent of the variance in every sample. The reliability of the regression in general being established, it is only necessary to refine the experimental and statistical methods to the highest practicable point.

The errors of estimate are attributable to both sources of error, and the direct regression may be used (making hemacytometer counts Y and colorimeter readings X) to estimate the appropriate variate with the least error. Winsor (1946) showed that such a procedure was proper when a random sample from a general population was being used. Since debris caused positive readings at zero concentration, the intercept value is given as a_x, instead of the conventional a_y, in the tables. The relationship is $a_y = -a_x/b_{yx}$, where $Y = a_y + b_{yx}X$.

Scatter diagrams of the data showed that the relations were rectilinear, at least within the range of sperm concentration and dilutions which were tested.

Diluting Fluid

A 4 percent solution of chlorazene in distilled water was found most satisfactory as a diluting fluid. It gave highly significant regression coefficients

for estimating hemacytometer counts, table 1, and was the only diluter capable of dissolving clumps which appear in many semen samples. One molar salt solution apparently precipitated proteins, as it gave much higher readings than the other diluters. The 0.1 M. NaCl and the 0.1 m. phosphate buffer at pH 7.0 gave significantly higher readings (regression) than chlorazene, but did not dissolve the clumps.

TABLE 1. REGRESSION DATA FOR RAMS' SEMEN, WHERE COLORIMETER READINGS ARE Y's AND HEMACYTOMETER COUNTS ARE X's*

Source of data; and year	SX	ST	Sx^2	Sy^2	Sxy	D.f.	Mean square	b_{xy}	a_x
Chlorazene at 1:50 (1945)	13,800	16,282	129,107	674,282	263,215	40	3,441.4	2.039	138.4
Chlorazene at 1:100 (1945)	8,634	16,282	71,363	674,282	205,232	40	2,101.4	2.876	70.8
Chlorazene at 1:200 (1945)	5,074	16,282	31,123	674,282	136,514	40	1,887.4	4.386	32.4
NaCl, 0.1 M. 1:100 (1946a)	6,044	9,617	75,793	442,903	167,438	18	4,056.0	2.209	84.5
NaCl, 0.1 M. 1:200 (1946a)	3,422	9,617	48,390	442,903	121,860	18	7,556.9	2.518	−19.8
PO_4 buffer at 1:100 (1946b)	4,188	6,321	196,943	576,279	320,744	18	1,343.6	1.674	20.6
PO_4 buffer at 1:200 (1946b)	2,309	6,321	76,021	576,279	204,136	18	1,562.3	2.685	−2.3
Chlorazene at 1:100 (1946b)	3,434	6,321	139,400	576,279	274,913	18	1,839.9	1.972	11.4
Chlorazene at 1:200 (1946b)	1,875	6,321	42,004	576,279	149,932	18	2,283.4	3.570	5.3
Chlorazene at 1:200 (1946c)	8,796	27,724	127,852	1,982,395	478,983	100	1,879.4	3.746	13.7
Chlorazene at 1:200 (1946d)	11,776	34,823	159,674	2,634,511	615,502	133	1,969.2	3.855	20.4
Debris score of 1	2,612	8,624	11,309	160,017	39,723	23	890.9	3.512	6.3
Drbris score of 2	3,466	11,358	39,309	596,817	144,940	31	2,012.7	3.687	11.7
Debris score of 3	2,946	8,222	39,493	590,364	148,071	40	880.0	3.749	17.9
Debris score of 4	1,334	3,139	18,596	195,138	54,846	16	2,086.1	2.949	15.0
Debris score of 5	1,418	3,480	17,464	321,214	71,926	15	1,665.7	4.118	33.7
Within groups			126,170	1,863,550	459,506	129	1,473.3	3.642	16.4
Combining groups 1 and 2			50,622	756,842	184,657	56	1,486.7	3.648	10.3
Group 3			39,493	590,364	148,071	40	880.0	3.749	17.9
Combining groups 4 and 5			36,816	524,388	129,237	33	2,143.1	3.510	24.7
Within groups			126,931	1,871,594	461,965	131	1,452.5	3.639	16.3
Washed sperm in chlorazene (1946e)	2,880	9,597	70,441	817,545	238,672	31	285.9	3.388	−1.4

* Data through 1946b were independently sampled, the rest have count and reading based upon the same diluted sample so that sampling errors were minimized.

Careful observation during a season's testing of rams has confirmed the authors' view that such clumping is largely independent of the ewe used for collection. Accessory gland fluids of the ram may have been responsible.

Examination of the regression coefficients, a and b, indicated that both were closely related to dilution, approaching zero at infinite dilution, for chlorazene. Such a relation was not apparent for either salt or phosphate buf-

fer. Opacity was apparently markedly altered by the latter two chemicals, but only slightly by chlorazene.

Mixtures of semen and chlorazene had the disadvantage of changing turbidity upon standing. However, no samples showed appreciable changes for 10 minutes after mixing, which is ample time for routine work. At the end of 15 minutes some samples gave increased readings and after 30 minutes some samples increased as much as 20 reading units (0.7 billion sperm per ml.). The samples finally assumed a yellowish tint, presumably due to liberation of chlorine through reaction of chlorazene and some constituent of the semen. The use of chlorazene was not feasable in complex experiments which required extended periods of time between dilution and reading. Dilutions with salt and phosphate buffers exhibited no appreciable changes.

Rate of Dilution

Dilutions of 1:50, 1:100 and 1:200 were tried for chlorazene and the latter two for salt and phosphate buffer solutions, table 1. All dilutions were made with 10 ml. of diluting fluid and the appropriate volume of semen to give the required dilution.

The dilution of 1:200 proved to be most desirable although it was not significantly better than the 1:100 dilution. The 1:200 dilution gave readings in the range of unit markings on the scale and required the least semen of the dilutions tested. The use of smaller volumes of semen for dilution is desirable because some ejaculates are too small for lesser dilution, the smaller volume is easier to draw into the pipette and it is more economical when semen is used for artificial insemination. The 1:50 dilution was unsatisfactory because the colorimeter readings were in a less precise range of the scale, they were more variable than higher dilutions, and the *a* value of the regression equation was much higher.

For other colorimeters and semen from other animals the proper dilution would have to be determined.

Effect on Colorimetry of Visible Debris in Semen

Readings and counts were first made on 102 samples diluted with 4 percent chlorazene at 1:200, table 1. Each count was made from the diluted sample used for colorimetry. The scatter diagram of these data revealed that some readings were high in comparison with the corresponding counts but that none was low. It was noted that some of the samples, with the marked discrepancy between reading and count, contained large amounts of debris. Salisbury *et al.* (1943) noted that the debris in the semen from some bulls caused abnormal readings, but they did not consider the problem further.

Arbitrary scores for presence of debris in the semen were established to

determine whether the correction of readings for debris score would increase their reliability in estimating concentration. Debris was scored at the same time as motility in the hanging drop of semen at 37.5° C. as follows: (1) practically free of debris; (2) debris present to a slight degree; (3) debris present to a moderate degree (there appears to be one-half as much debris as sperm); (4) debris present to a marked degree (there appears to be as much debris as sperm); (5) debris present to an extreme degree (there appears to be more debris than sperm).

Debris scores were used to group the data in a new sample of 135 ejaculates, table 1, 1946d. The reduction in mean square due to grouping by debris scores was highly significant. When the variance due to means was removed, the residual mean square was significantly greater than would be expected by random grouping of the data. The differences among regressions for the five separate groups of data were not significant, and did not show any tendency to fan out, as might be expected from the description of the scores. The intercept values, a were significantly different and showed an irregular progression related to score.

Examination of a scatter diagram of the data revealed that the scoring process had evidently divided the ejaculates into groups with similar regression coefficients and different intercept values. The intercept values of scores of 1, 2 and 3 were nearly identical, and the data for scores of 4 and 5 overlapped considerably. The data were regrouped by combining scores in several different ways. It was found that the minimum error of estimate was obtained by the combination, 1 and 2 scores, 3 score and 4 and 5 scores to give three groups. The regression coefficients were not significantly different, but the intercept values were. When grouped this way the data were not significantly more accurate than using five groups separately but were simpler to use, since only three values need be known for each colorimeter reading to estimate concentration.

The authors used tables constructed from the equation, $Y = a_y + b_{yx}X$, where the regression coefficient, b_{yx}, was 3.639 and the intercept, a_y, was -37.4 for scores of 1 or 2, -65.1 for score of 3, and -89.9 for scores of 4 or 5, to convert colorimeter readings to concentration expressed as 10^7 sperm per ml.

Effect on Colorimetry of Residual Turbidity after Centrifugation

The finer particles, which remained in suspension after centrifuging the diluted samples for 30 minutes, were significantly related to total turbidity and concentration when a salt diluter was used. This residual turbidity, using a phosphate diluter, was significantly related to total turbidity but not to concentration counts. The two diluters apparently differed in their effect

on residual debris. The residual debris appeared to be unrelated to debris as a whole.

Effect of Sperm alone on Turbidity

To determine the effect of sperm-alone on turbidity it was necessary to remove, as nearly as possible, all of the debris from the sample. A 10 ml. pool of ejaculates, with high sperm concentration, was centrifuged and resuspended in 0.1 M. phosphate buffer. This process was repeated three times. The phosphate buffer was necessary because of change in reading on standing with the chlorazene diluter. After each centrifugation the supernatant fluid was decanted and the top of the packed sediment was removed to eliminate small particles. The final dilution was adjusted to give approximately 1.5 billion sperm per ml. Eighteen dilutions were made using from 0.01 ml. to 0.18 ml. of the above sperm suspension in 10 ml. of chlorazene.

The relation of readings to counts from the diluted samples, table 2, revealed that the sample closely approached a true base line in that none of the *a* values was significantly different from zero. The regression coefficient, however, was significantly different from that for normal counts. This difference was likely due to the effect of the phosphate buffer while removing the debris, as the phosphate buffer altered opacity more than chlorazene in earlier tests.

Effect of Pipette on Colorimetry

In the preceding section the experiment was designed to permit testing of pipette variation and the effect of rinsing the pipette into the diluter (regularly practiced). Duplicate series were made with two different brands of pipettes. The higher concentrations, requiring 0.11 to 0.18 ml., were made by letting the pipette drain for the first fraction and then refilling to 0.1 ml. and rinsing the pipette into the diluter. Readings were then related to coded concentrations which would be true relative concentrations if there were no errors due to pipettes or technique of dilution, table 2.

Brand A pipettes were not significantly more variable than Brand B, but had a lower effective volume since they gave significantly lower readings. Brand B pipettes drained with greater uniformity than A pipettes as evidenced by their significantly lower error of estimate, in the higher concentration group of data. It is preferable to use one brand of pipette to reduce error due to differences in pipettes. A significant amount of semen adhered to the wall of the pipette, and the amount varied between brands. The pipette should be rinsed into the diluter to eliminate this source of error.

Accuracy of the Methods

To obtain estimates of sampling error for the colorimeter and hemacytometer, duplicate samples were measured and the resulting data analyzed.

Twenty samples were run in duplicate for the colorimeter, using chlorazene at 1:200. The within sample standard deviation was 5.43 (10^7 sperm per ml.). The standard deviation for the colorimeter was multiplied by the regression coefficient, 3.639, to give a proper comparison with the hemacytometer. The adjusted value was 19.7 for the colorimeter. The standard deviation for duplicate hemacytometer counts from 48 ejaculates was 26.1. These values contain sampling errors due to dilution, heterogeneity of semen, variability

TABLE 2. REGRESSION STATISTICS FOR SEMEN SAMPLES WITH THE DEBRIS REMOVED

Source of data	SX	ST	Sx^2	Sy^2	Sxy	D.f.	Mean square	b_{yx}	a_x
Tests of the base line. (colorimeter readings, X, and concentration counts, Y)									
Total	2,880	9,597	70,441	817,545	238,672	31	285.9	3.388	−1.44
Brand A pipettes	1,248	4,124	26,128	275,449	84,166	14	308.9	3.221	−2.01
Brand B pipettes	1,632	5,473	41,642	508,133	144,982	15	224.0	3.482	3.53
Within brands			67,770	783,582	229,148	30	292.4	3.381	−1.26
Tests of pipette variation (colorimeter readings, X, and relative concentration, Y)									
Total, for concentrations of 1–10	1,133	110	18,727	165.0	1,747.5	18	0.1072	.0933	
Brand A	541	55	9,945	82.5	904.5	8	0.0295	.0910	
Brand B	592	55	8,652	82.5	843.0	8	0.0449	.0974	
Within brands			18,597	165.0	1,747.5	17	0.0465	.0940	
Total, for concentrations of 11–18	2,144	232	6,616	84	681	14	0.9931	.1029	
Brand A	1,012	116	2,814	42	333	6	0.4323	.1183	
Brand B	1,132	116	2,902	42	348	6	0.0448	.1199	
Within brands			5,716	84	681	13	0.2220	.1191	

in the instruments, worker errors, and distributional errors (Poisson). The colorimeter values contain the additional factor of heterogeneity of semen in regards debris.

When the variance attributable to Poisson (variance equals mean) was removed from the within sample hemacytometer variance, the resulting standard deviation for the hemacytometer became 21.4, slightly higher than the colorimeter value of 19.7. Thus the two instruments were basically similar for sampling errors.

The technique which the authors adopted (1:200 dilution with 4 percent chlorazene, scores grouped into 1 and 2, 3, 4 and 5) gave a standard error of estimate of 38.1. The error of estimate for these data without grouping was 44.4, making the error of estimate attributable to scoring 22.7. Comparing these data to the washed sperm data, an additional reduction with an

error of estimate of 34.1 should be effected if debris were perfectly scored, and the samples were homogenous. Apparently, scoring accounts for nearly one-third, 30.7 percent, of the possible reduction in variance attributable to debris and heterogeneity of sample.

Summary

Over 300 ejaculates from about 100 rams were exmained at the U. S. Sheep Experiment Station and Western Sheep Breeding Laboratory during annual Fall testing of rams. The relations between counts of sperm made with a Spencer Brightline hemacytometer and turbidity readings made with a Klett-Sommerson photoelectric colorimeter were analyzed by regression and covariance methods.

Diluting fluids had significantly different effects on opacity of the diluted semen. Chlorazene was the diluter of choice, despite its change upon prolonged standing, because it was the only diluter capable of dissolving clumps which were prevalent in rams' semen.

A dilution of 1:200 gave the optimum range of readings in the colorimeter scale, lower effect of debris, and lower error of estimate.

Scores were established for estimating the amount of visible debris in the samples. Highly significant improvement in colorimetric estimation of sperm concentration was effected by scoring the amount of debris.

Non-visible elements of debris, measured as residual turbidity after centrifugation of diluted samples, contributed appreciably to the colorimeter readings. This residual turbidity could not be used as an estimate of total debris.

The colorimeter readings of semen with the debris removed gave a regression line with the intercept point not significantly different from zero.

Two brands of diluting pipettes showed no differences in variability when rinsed into the diluted sample. They did show significant differences in volume and ability to drain without rinsing.

The technique adopted for use (chlorazene at :1200 with scoring of debris) gave a standard error of estimate of 38.1 (10^7 sperm per ml.). The error due to workers and instruments was negligible. The standard deviations for the two instruments were similar, 21.4 and 19.7, for sampling and dilution, but the hemacytometer was slightly less accurate, 26.7, because of its higher variance due to the Poisson distributional error of the smaller volume measured. The error of estimate attributable to scoring of samples for amount of debris was 22.7, while the error for debris and heterogeneity which could not be scored was 34.1.

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ABSTRACTS OF PAPERS TO BE PRESENTED AT THE THIRTY-NINTH ANNUAL MEETING OF THE AMERICAN SOCIETY OF ANIMAL PRODUCTION

The meetings are scheduled to be held at the Hotel Sherman in Chicago on November 28 and 29, 1947, with a dinner for the honor guest on November 30.

Breeding and Genetics Section

J. L. Lush, *Chairman*

HERITABILITY ESTIMATES OF SOW PRODUCTIVITY AND LITTER PERFORMANCE. Cecil T. Blunn and Marvel L. Baker, *University of Nebraska.*

Criteria used to evaluate sow performance were total number of pigs farrowed, born alive, alive at 21, 56, and 168 days of age, as well as litter weight at 56 and 168 days. These factors were adjusted for age of sow, inbreeding of sow and inbreeding of litter before heritability estimates were determined. A total of 561 litters farrowed in the Nebraska swine breeding project from 1937 to 1943, inclusive, were used. Heritability estimates were obtained by doubling the intra-sire regression of daughter's performance on sow's performance (based on 478 daughter-dam pairs). These were compared with intra-line estimates of heritability based on paternal half-sib and full-sib correlations. Estimates of heritability based on full-sib correlations varied from 0.05 for litter weight at 168 days to 0.15 for number of pigs alive at weaning. For paternal half-sib correlations, estimates varied from 0.08 for number of pigs alive at 21 days to 0.17 for litter weight at 168 days. Based on intra-sire regressions, heritabilities varied from 0.02 for number of pigs alive at 56 days to 0.59 for number of pigs born alive. Sow productivity is a combination of a progeny test of the sow and a measure of her direct environmental influence on the litter. The more important a pig's own genes are for a given character, the more litter performance becomes a progeny test for the dam. Litter weight at 168 days, therefore, is more a progeny test than a measure of sow performance.

PERFORMANCE TESTS OF MORGAN HORSES UNDER SADDLE. W. M. Dawson, Ralph W. Phillips, and E. B. Krantz, *United States Department of Agriculture.*

One-mile tests at the walk and at the trot on an exercise track and an eleven-and-a-half-mile cross-country ride (each horse walked 4.7, trotted 5.7, and cantered 1.1 miles) have been conducted since 1941 on three-year-old Morgan horses raised and trained at the U. S. Morgan Horse Farm, Middlebury, Vermont. Horses carried 20 percent of their weight and were tested at their "normal" gait. Eleven which tended to pace were omitted. Analyses of variance of 68 horses that trotted naturally showed significant differences in time required for the cross-country ride, time required to walk a mile and length of stride at the trot for the offspring of eight sires. Significantly less time was required on both the cross-country ride and the mile test by horses with the longest stride at the trot. Correlations between the time required for the cross-country ride and the time required for the mile test at the walk and the trot were 0.42 and 0.35, respectively. Horses given the best scores by the riders for performance of the walk were ones with the fastest time and longest stride. Those given high scores on ease of walk to rider also tended to have a long stride. Effects of numerous body measurements and scores of conformation, as well as scores of temperament, condition, quality and style, on performance, are discussed.

PERFORMANCE OF INBRED LINES AND LINE CROSSES IN SWINE. G. E. Dickerson, J. L. Lush, M. L. Baker, J. A. Whatley, Jr., and L. M. Winters, *Regional Swine Breeding Laboratory, United States Department of Agriculture and cooperating states.*

The effect of inbreeding on performance was estimated from comparison of inbred and linecross litters in four projects of the Regional Swine Breeding Laboratory. Litter inbreeding was studied using differences between inbreds and 2-line crosses, within season and line of dam. Durocs included 298 inbred and 167 line cross litters of 14 lines and 33 crosses; Poland Chinas comprised 240 inbred and 158 line cross litters of 17 lines and 66 crosses. Average inbreeding of lines varied from 23 to 42 percent in four projects. For each 10 percent rise in litter inbreeding, independent of age and inbreeding of dam, the decline averaged in litter size, 0.2 pigs* at birth, 0.4 pigs** at 21 days and 0.5 pigs** at 56 and 154 days; in pig weight no decline to 56 days but 3.6 pounds** at 154 days. Rate of decline was similar for the same breed in different projects, but was faster for Durocs than for Polands, especially in litter size. For Poland Chinas at one station, comparison of 2-line and 3-line crosses indicated that for each 10 percent rise in inbreeding of dam, litter size declined 0.16 pigs at birth and 0.22 to 0.25 pigs* at 21 to 154 days of age, pig weight declined 0.05 pounds at birth, 0.17 pounds* at 21 days with no effect at later ages. Time trend in performance of inbreds indicated linear inbreeding decline as large or larger than that based on inbred line cross comparisons, with small and nonsignificant line differences in rate of decline. (* $P<.05$; ** $P<.01$)

SELECTION OF YOUNG DAIRY BULLS BY METHODS USING MAXIMUM INFORMATION IN THE PEDIGREE. Franklin Eldridge and G. W. Salisbury, *Cornell University.*

Several investigators have determined the correlations between the average butterfat production of the offspring of a dairy bull and the average production of different groups of his relatives. However, no study has been previously reported in which these correlations derived from information on the same groups of relatives in each of the pedigrees of a large number of dairy bulls, have been combined into one analysis. In the New York State herd analysis program and U.S.D.A. proofs on Holstein sires, there were a large number of bulls having five or more daughters with production records as well as butterfat production records on; (1) the dam of the bull, (2) the maternal half-sisters of the bull, (3) the paternal half-sisters of the bull, (4) the dams of the paternal half-sisters of the bull, (5) the paternal half-sisters of the dam of the bull and (6) the mates of the bull. These data were used to determine how much each of the items should be weighted in one regression equation to give the most reliable estimate of the actual production of the daughters of a bull. It was found that the regression equation accounted for about 48 percent of the variability in the average butterfat production of the daughters of these bulls. The most important variate affecting the average production of the daughters was the average production of their respective dams (r equal approximately to $+0.67$). After the deletion of this variate, the equation still accounted for 14 percent of the variability, a highly significant portion.

THE EFFECTS OF ENVIRONMENTAL AND HEREDITARY FACTORS ON TRICHOSTRONGYLID WORM INFESTATION ON SHEEP. L. Otis Emik and Paul W. Gregory, *University of California.*

Statistical measures of environmental influences and estimates of heritability for resistance of sheep to trichostronglyids were sought. Counts of parasites' eggs were made on fecal samples taken at weekly intervals for 12 weeks. The lambs (10 Southdown, 12 Shropshire, 36 Hampshire, 20 Merino, and 25 Rambouillet) constituted the major portion of the lamb crop at University of California, Davis, in 1939. Age of the lambs was not correlated to infestation level (as measured by mean square root of counts). Environmental effects were estimated by analysis of variance of the square roots of the counts. The main effects were adjusted for unequal subclass numbers. Sex, breed, day, sire, twin, type and sheep were all significant. The presence of interaction between days and the other factors indicated that days largely represented independent sampling rather than any time trend. The highly significant Sex×Type

interaction points to a definite sex difference between the mutton and wool types in relation to infestation. The females were responsible for most of the difference. The Breed×Sex interaction was still significant when corrected for type, but largely due to type differences. Heritability as estimated by full-sib correlation was $0.56 \pm .54$ and by half-sib correlation in Hampshires it was $0.25 \pm .64$. The high standard errors offset the otherwise encouragingly high estimates of heritability. Studies of inherited resistance are exceedingly complex under these circumstances and proper design of experiment will be necessary to insure the success of future research.

COMPARISON OF CORRIEDALE × NAVAJO AND ROMNEY × NAVAJO CROSSES. James O. Grandstaff, *United States Departments of Interior and Agriculture, cooperating.*

At the Southwestern Range and Sheep Breeding Laboratory, Fort Wingate, N. Mex., old-type Navajo ewes were mated to purebred Corriedale and Romney rams, and some ½ and ¾ Navajo ewes were backcrossed to Romney rams. From 1937 to 1942 inclusive a total of 905 matings were made, using six rams of the Corriedale breed and six of the Romney breed. These matings resulted in an average of 89 percent of pregnant ewes for each cross. The Corriedale cross was superior to the Romney cross in percentages of lambs born and reared and in rate of growth of lambs from birth to weaning age. Mean differences in weaning weights of lambs and in the poundage of lamb produced per ewe bred, of 3.9 pounds and 15.4 pounds respectively, were highly significant. A total of 283 ewe lambs were saved as breeding prospects, the percentage of culled lambs being significantly greater for the Romney than for the Corriedale cross. At yearling age there was no significant difference between the Corriedale and Romney crossbred ewes, in body weight or length of staple. The ewes sired by Romney rams had coarser fleeces containing more kemp and other medullated fibers, but the fleeces of the Corriedale F_1 ewes were heavier and yielded a greater amount of clean wool. Differences between crosses with respect to fleece, weight, yield of clean wool, fiber-diameter, and percentages of kemp and other medullated fibers were highly significant.

SELECTION IN AN INBRED LINE OF DUROC SWINE. R. C. Laben and J. A. Whatley, Jr., *Oklahoma A. & M. College.*

The intensity of selection for certain traits was determined in Line 3 of the Oklahoma swine breeding project. This was a closed line, bred for 6 generations from a foundation of 3 boars and 10 sows. From 1938 through 1946, 33 boars and 85 sows produced 147 litters. The average inbreeding of the 816 pigs raised to 180 days was 16 percent. There was a uniform increase in inbreeding to 24 percent in the fourth generation, followed by a decline to 19 percent in the sixth generation. Selected individuals averaged 22 pounds heavier than their generation at 180 days, but the weight decreased from 187 pounds in the first to 153 pounds in the fifth generation. The conformation score of selected individuals was 2.3 points above their generation averages. Generation average scores did not change noticeably. Size of litter weaned decreased from 6.7 pigs in the first generation to 6.0 pigs in the fifth and 4.3 pigs (only 6 litters) in the sixth generation. This decline occurred in spite of selecting breeding stock from litters 1.2 pigs larger than the average. Dams of selected individuals were 2.5 points superior in production index to the 45.5 point average of dams of all pigs. Approximately 50 percent of the selected sows had descendants in the line at the close of the study. These "effective" sows were superior to the selected sows in 180 day weight and productivity.

THE FERTILITY OF BOVINE SPERMATOZOA TREATED WITH IMMUNE SERA FOR THE CONTROL OF TRICHOMONIASIS. Banner Bill Morgan, *University of Wisconsin.*

One hundred and one cows and heifers were artificially inseminated with semen from a trichomonad infected bull and semen from a normal bull to which *Trichomonas foetus* had been added. The semen was diluted with raw or hyperimmune bovine sera for the purpose of inactivating or destroying the trichomonads. Twenty cows became pregnant and calved normally (19.8%). Artificial insemination of twenty control animals with normal undiluted

semen resulted in 17 pregnancies. Twenty control cows bred artificially with semen from an infected bull resulted in 4 normal calvings; 16 cows contracted trichomoniasis. This method cannot be placed on a practical basis until the spermaticidal effects of bovine sera can be removed.

REACTIONS OF SOUTHDOWN SHEEP TO TWO ENVIRONMENTS. Ralph W. Phillips and Damon A. Spencer, *Food and Agriculture Organization of the United Nations and United States Department of Agriculture.*

Comparisons were made of reactions of Southdown sheep to environments at Beltsville, Maryland and Middlebury, Vermont. In one comparison the flock was transferred from Beltsville to Middlebury and returned to Beltsville after failing to thrive in Vermont. In another, lambs were transferred from Middlebury to Beltsville, and their performance compared with that of animals born and raised at Middlebury. In the first comparison, ewes of all ages were lighter at Middlebury than at Beltsville before leaving and after their return. Lambing percentages were also generally lower at Middlebury. There were no important differences in birth weights at the two locations but weaning weights were generally lower at Middlebury, the average difference being about 10 pounds. Fleece lengths and weights were lower in all age groups at Middlebury. In the second set of comparisons weaning weights were not available but there were no consistent indications of differences in performance at Middlebury and Beltsville with the exception that ewes at Middlebury were heavier in all age groups for which data were available. The animals used in the second set of comparisons were of a larger, more rugged type than those used in the first set, and may have been better adapted to conditions at Middlebury. Other possible factors affecting the results are discussed. The findings indicate the importance in livestock production of variations in adaptability to environment and point to the need for greater attention to such problems in animal husbandry research.

THE RELATION OF FACE COVERING TO LAMB PRODUCTION IN RANGE RAMBOUILLET EWES. Clair E. Terrill, *United States Department of Agriculture.*

Previous work has shown that Rambouillet ewes with open faces produce more pounds of lamb than those with covered faces. Because these results indicated a significant economic importance for face covering, this study was extended using the lifetime lamb production of 798 Rambouillet ewes born during the years from 1938 to 1940 at the Western Sheep Breeding Laboratory, Dubois, Idaho. Ewes with open faces produced 11.2 more pounds of lamb per year during their lifetime than those with covered faces. Ewes with partially covered faces produced 7.7 more pounds of lamb per year than those with covered faces. These differences occurred in spite of three periodic clippings around the eyes of all ewes subject to wool blindness. The advantage of open-faced ewes in lamb production was apportioned to specific phases of reproduction. About 46 percent of the advantage of open-faced ewes was due to a greater number of lambs born per ewe lambing; 26 percent was due to higher weaning weights; 19 percent was attributed to a higher proportion of the open-faced ewes becoming pregnant; and 9 percent was due to greater viability to weaning of offspring from the open-faced ewes as compared to those with covered faces. The greatest advantage for open-faced ewes was found at 3 years of age followed in order by 2, 4, 6, and 5 years. These results confirm previous work and emphasize the economic importance of open face in range sheep.

THE HERITABILITY OF MILK AND BUTTERFAT PRODUCTION AND PERCENTAGE OF BUTTERFAT IN AYRSHIRE CATTLE. W. J. Tyler and George Hyatt, Jr., *West Virginia University.*

Data on the production of 6888 daughters and mates of 374 Ayrshire sires were used in this study. All milk and butterfat records were converted to a 305-day mature equivalent twice-a-day milking basis. Twice the intra-sire regression of daughter's production performance on dam's performance was used to estimate the heritability of differences in single unselected records of milk and butterfat and the percentage of butterfat. The estimates were 31 28 and 55 percent respectively. The observed phenotypic relationships between these vari-

ables for the same cow were 0.93 between milk and butterfat production, −0.14 between milk production and percentage of butterfat, and 0.23 between percentage of butterfat and butterfat production. The corresponding genetic correlations between these variables were 0.85, −0.20 and 0.26. The results of this study indicate that butterfat test is about twice as heritable as milk and butterfat production. Approximately 20 percent of the heredity that influences milk and butterfat production also affects the percentage of butterfat in the milk. On the other hand, about 85 percent of the animal's genotype that influences milk production also influences the production of butterfat.

A STUDY OF LAMB MORTALITY. G. Venkatachalam, R. H. Nelson, Frank Thorp, Jr., and R. W. Luecke, *Michigan State College.*

The birth records and autopsy reports were analyzed from a flock of sheep for the three years 1945 through 1947. The flock contained the six breeds, Shropshire, Hampshire, Oxford, Rambouillet, Southdown, and Cotswold. During the period studied there were 312 pregnancies resulting in the birth of 483 lambs (including stillbirths). Of these 483 lambs, 136 died during the first two months for a mortality rate of 28.2%. No significant difference in mortality rate between years was found. The sex ratio at birth showed a larger percentage of males than females. Differences in mortality rate between sexes were studied and the percentage for ram lambs was found to be higher than that for ewe lambs. Mortality of twin lambs was 35% as compared to 20% of lambs from single births. A study of the post-mortem reports showed that unknown factors, pneumonia, overlaying and patent foramen ovale (open heart valve) were the most important causes of death. Over causes included injuries, bacteraemia, navel infection, coccidiosis, over-eating and freaks. The records indicate a difference in mortality rate between breeds and between offspring from different sires within breeds.

Extension Section

L. K. Bear, *Chairman*

SOLUBLE FLUORIDES AS SWINE ANTHELMINTICS. W. P. Elmslie, Paul Caldwell, and R. A. Sturdy, *Moorman Mfg. Company.*

The large roundworm of swine presents a serious problem in swine raising which is not always handled through sanitation alone. A very efficient method of removing this parasite of swine, through the inclusion of sodium fluoride or other soluble fluorides in the feed has been perfected and the development of this method is described. Data are presented on the effectiveness and safety for this purpose of various soluble fluorides. The use of a saline laxative in conjunction with a soluble fluoride has been found to increase the efficiency and also the safety of the treatment. The use of calcium-containing minerals or of milk in the pigs' ration during the treatment has been found to decrease the efficiency. Permitting access to certain types of pasture has also been shown to lower the effectiveness to some extent.

A COMPREHENSIVE STUDY OF BRUISE LOSSES IN SWINE. Harold A. Henneman and Ralph May, *Wilson & Co.*

From March, 1946 to September, 1947, weekly tests were made on good and choice butcher hogs selected at random to determine, (1) the monetary loss per head slaughtered; (2) the age, location and cause of bruises; and (3) variation in bruising by seasons, weight of hogs and distance hauled. Both truck and rail lots were used in securing data on 1082 carcasses. Bruise trim was weighed and monetary discount recorded on trim and degraded cuts. Thirty-nine percent of the test hogs were bruised. Of the wholesale cuts, 25.5 percent of the hams were bruised; 15 percent of the fatbacks; 2 percent of the loins; 5.6 percent of the bellies, and 6.8 percent of the shoulders. Bruise causes were, 40.4 percent by cane, whip or club; 18.7 percent by kicking or prodding; 18.4 percent by crowding and trampling; 10.1 percent by fork, nail or puncture; 1.6 percent spreaders and 10.8 percent due to other causes; 48.6 percent of the bruises occurred on the farm before loading. Average monetary loss per head slaughtered due to bruising was 19 cents, of which 9 cents was trim and 10 cents degrading loss. Loss per

head bruised was 48 cents. Average losses on rail hogs was 19.4 cents per head and truck hogs, 18.6 cents per head. Hogs weighing 200 to 250 pounds had an average loss per head of 16.2 cents; 250 to 300 pounds hogs 20.4 cents; and 300 to 350 pounds hogs 23.8 cents. Hogs hauled 50–100 miles had an average loss of 11.2 cents per head; 100–150 miles, 17.3 cents and 150–200 miles, 21.6 cents per head.

MICHIGAN SOW TESTING AND SWINE EXTENSION SWINE FEEDING PROJECTS. H. F. Moxley, Graydon Blank, and W. N. McMillen, *Michigan State College.*

The Michigan Sow Testing Program is in its third year. Over 800 litters have been weighed at weaning time. Each year it has been observed that the 10 high litters weigh about the same as the 30 low litters.

The Sow Testing Program has been a means of extension contacts to improve feeding and management in counties and communities where weaning weights have been low. There is an increasing interest in litter data in sale catalogs and a noticeable increase in sale value of good gilts with production data. A summary of the sow testing data for the three years and some of the effects it is having on swine production and extension methods is to be presented.

The Michigan Swine Breeders' Association and Animal Husbandry Extension sponsor a Michigan Winter Swine Feeding Contest and Show. Pigs must be farrowed after August 1 and weighed in under 90 pounds of weight before November 15. Feed records must be kept on the group of pigs fed and the pigs must gain an average of 1.4 pounds daily to qualify for the show. The prize winning barrows are slaughtered and awards are also made in the Carcass Show. Having feeding records, placing on foot and in the carcass make this program very educational from production and marketing standpoints. The average feed-lot data and the effectiveness of this program from an extension standpoint are to be discussed.

Meats Section

D. E. Brady, *Chairman*

AN INDEX FOR ESTIMATING PORK CARCASS YIELDS. L. J. Bratzler, E. D. Farwell, and W. N. McMillen, *Michigan State College.*

In cooperation with The Detroit Packing Company individual weights and measurements were taken on 478 hogs from 17 breeds and crossbred groups. Slaughtering and cutting was done by packing company personnel and represented their normal methods. Through development of a specialized technique, it was possible to secure the data at five different two-hour cutting periods. The following data were tabulated on each hog: live weight; cold carcass weight; carcass length from aitch bone to first rib; weight of each of the primal cuts, trimmed loin, belly, skinned ham, and New York style skinned shoulder; and the weight of the fat back. A highly significant correlation coefficient of +0.820 was found between the yield of primal cuts from the carcass and the relationship of trimmed loin to fat back. Also a highly significant, although somewhat lower, correlation coefficient of +0.561 was found between the yield of primal cuts on a live weight basis and the relationship of trimmed loin to fat back. These results indicate that the trimmed loin—fat back ratio is a reliable index for estimating the yield of primal cuts from a hog carcass.

BACTERIOLOGICAL STUDIES RELATING TO THERMAL PROCESSING OF CANNED MEATS. C. E. Gross, *John Morrell & Company.*

Thermal resistance of putrefactive anaerobic spores in meat has been studied. Studies include determination of thermal resistance for spores: formed in laboratory media; formed in raw, pasteurized and sterilized meat; and normally occurring in meat. Curing agents in amounts permitted for use in federally inspected plants did not affect the level of heat processes required for sterilization. The thermal process for destruction varied directly as the concentration of spores. Salt inhibited germination of spores surviving thermal processes and was quite effective at a level of 3.33 percent. Spores surviving the thermal processes were shown

to be viable two and a half years later. The thermal resistance of spores is less when grown in raw meat or organs and increases when grown in either pasteurized or sterilized meats and organs. The average increase amounts to approximately three times. The effect was shown to be related to the substrate itself through repeated raising and lowering of resistance by transfer from media to media. These data correlate with studies on the processing levels necessary for sterilization of spores normally occurring in commercial meat and organs. The hazard of drawing conclusions of commercial significance from laboratory experiments is emphasized. These studies permit drawing conclusions of practical commercial significance.

SANITATION FROM THE SLAUGHTERING FLOOR TO THE CONSUMER. C. H. Pals, *United States Department of Agriculture.*

Sanitary handling of meat involves attention to a wide variety of factors. Such a program should include provision for preventing contamination with harmful bacteria, molds and yeasts, insects, rodents, excreta from insects, rodents and other animals, harmful chemicals, hair, dust and other filth. Buildings and equipment should be so constructed to as permit them to be readily cleaned and maintained in a sanitary condition. Facilities should be provided which will include an adequate supply of hot and cold water under pressure, well distributed throughout all operating departments, adequate lighting which is well distributed and of good quality, and proper ventilation. The recent increase in the amount of meat and meat food products being packed in consumer-sized packages will decrease the contamination which results from the repeated handling of products. More attention should be given to using suitable protective coverings on all meat and product during the time it is being transported. Separate equipment of proper design for eviscerating and handling poultry and fish should be provided in retail stores. Persons handling meat should be free from communicable diseases and from conditions such as boils and infected wounds which might contaminate meat.

Nutrition Section

T. S. Hamilton, *Chairman*

THE ADEQUACY OF SYNTHETIC RATIONS FOR SWINE. G. C. Anderson and A. G. Hogan, *University of Missouri.*

Three Chester White pigs were allowed to nurse their mother for three days, and were then transferred to an artificial milk prepared by adding water to a synthetic diet. The synthetic diet contained all of the vitamins now recognized, including pteroylglutamic acid, but it contained no crude vitamin carriers. The pigs were subject to diarrhea at first, and grew at a moderate rate. During the last four weeks the pigs grew at a tremendous rate and the average weight at 8 weeks was 35.8 lbs. This trial was repeated, with some modifications, but with a lesser degree of success. The pigs were Spotted Poland Chinas and they were kept continuously on wide mesh screen floors. The average weight of the three pigs at 8 weeks was only 21.9 lbs., but they seemed reasonably healthy and thrifty. The difference in response of the two groups may have been due to differences in genetic makeup, or in the environment, or it may be the diet is not entirely adequate.

One of the Chester White pigs, a female, was retained and was carried through a reproductive cycle. She farrowed 11 living pigs, but became severely anemic, stopped lactating and died on the 55th day after farrowing. The 5 surviving pigs were reared on the synthetic diet with no difficulty and when 8 weeks old their average weight was 24 lbs. So far as can be determined now they are normal.

THE EFFECT OF THYROPROTEIN AND THIOURACIL ON THE GROWTH AND FATTENING OF SWINE. W. M. Beeson, F. N. Andrews, H. L. Witz and T. W. Perry, *Purdue Agricultural Experiment Station.*

In a preliminary investigation to determine the effect of thyroprotein and thiouracil on swine, purebred Duroc pigs averaging 53 pounds were fed for 84 days on a basal ration composed of 69 percent corn, 20 percent wheat, 10 percent Purdue supplement 5 and 1 percent

minerals. Thyroprotein was mixed in the basal ration at levels of 0.0044 percent and 0.0088 percent and thiouracil was fed at a rate of 0.1 percent for six weeks and then changed to 0.0088 percent thyroprotein. Thyroprotein fed at the 0.0044 percent level had no significant effect on the rate of growth. The pigs receiving 0.0088 percent thyroprotein gained 26 pounds ($P<0.05$) more in 84 days and required 10 percent less feed per pound of gain than the control group. Carcass measurements and weights of primal cuts were not significantly affected by thyroprotein when fed at the 0.0044 percent level; but when fed at the 0.0088 percent level, thyroprotein produced significantly longer carcasses, heavier bellies and heavier picnic shoulders. Feeding of thiouracil at 0.1 percent of the diet markedly retarded growth, reduced feed intake and caused the pigs to become very short and chuffy, sluggish, and to develop severe myxedema. Symptoms of myxedema were characterized by thickened skin, brittle and coarse hair, loss of hair in abdominal region, puffy legs, slow gait and asthmatic breathing. Due to the severity of the myxedema at the end of the sixth week, the thiouracil was replaced with 0.0088 percent thyroprotein. After one week on thyroprotein the symptoms of myxedema began to disappear and the hogs became more active and showed a marked increase in gain and appetite.

THE SIGNIFICANCE OF THE METABOLIC NITROGEN OF THE FECES IN THE ESTIMATION OF THE PROTEIN REQUIREMENTS OF RUMINANTS. K. L. Blaxter and H. H. Mitchell, *University of Illinois.*

The metabolic nitrogen of the feces, consisting of body constituents excreted with indigestible constituents of the feed in the feces, has heretofore been used merely in correcting apparent digestion coefficients to true digestibility. However, the materials containing this fraction of the fecal nitrogen must be replaced in the animal body if its integrity is to be preserved. Furthermore, its replacement from the food supply cannot be presumed to be 100 percent efficient. Hence, the metabolic fecal nitrogen becomes an item in the nitrogen requirement of the animal, an item that has not previously been considered. Since the metabolic fecal nitrogen varies with the dry matter consumed, and hence is greater the greater the fiber content of the ration for a given net energy requirement, this item in the total protein requirement is largest for rations high in fiber, such as those derived from poor quality roughage. In the immature ruminant in which the growth of new tissue is at its highest rate, some 20 percent of the requirement of truly digestible (metabolizable) protein is used in the replacement of the metabolic fecal loss, while at maturity over 60 percent of the total requirement is determined by this factor. This revision of the estimate of the protein requirement of ruminants by the factorization method brings the estimate into close agreement with experimental results obtained by feeding trials designed to determine absolute protein requirements for maximum growth.

THE YIELD AND FEEDING VALUE OF PRAIRIE HAY CUT AT DIFFERENT STAGES OF MATURITY. H. M. Briggs, W. D. Gallup, J. S. Dinning and A. E. Darlow, *Oklahoma Agricultural and Mechanical College.*

A prairie hay meadow was divided into four series of plots and the series have been harvested the third week in June, July, August and September each year for three years. Hay cut in June had an average yield of 0.91 tons per acre while the area cut in July averaged 1.17 tons and the August and September areas averaged 1.07 tons. The distribution of rainfall had an influence on the annual yield and composition. The crude protein content of the hay and its apparent digestibility tended to decrease as the season advanced. The July hay was found to have the highest total digestible nutrient value per acre when fed to yearling steers. The August hay ranked second in total feeding value per acre while June hay was the most valuable per pound. Prairie hay that was put up without getting wet lost approximately one-half its carotene the first month of storage but still contained an appreciable amount after being stored six months. The chemical composition of second-growth grass exhibited the same characteristic changes with age that were shown by first-growth grass.

PRELIMINARY OBSERVATIONS ON USING A SYNTHETIC MILK FOR RAISING PIGS FROM BIRTH. L. K. Bustad, W. E. Ham and T. J. Cunha, *State College of Washington.*

Pigs removed from the mother at birth and placed on a synthetic milk containing all known vitamins and with plasma or serum as colostrum substitutes failed to survive longer than 22 days. It was found that pigs fed no colostrum substitutes such as serum or plasma died very shortly after birth. This finding indicates that colostrum and serum or plasma contain something which is necessary for the survival of the pig. Indications were that plasma was superior to serum as a colostrum substitute for the new-born pig. A severe diarrhea developed with all pigs fed synthetic milk. The pigs gradually became unthrifty in condition and developed a dark exudate around the eyes which often cemented the lids together. The results obtained indicated that the ration used was inadequate. The addition to the ration of crude casein, lactose, 1–20 liver powder, or an anti-pernicious anemia liver extract was of no apparent benefit in prolonging life or improving the appearance of the pigs. The use of the following therapeutic agents was of no benefit in controlling the diarrhea that developed or in prolonging life: Penicillin, sulfathalidine, sulfamethazine and kaopectate.

THE NEED AND INTERRELATIONSHIP OF PTEROYLGLUTAMIC ACID, ERYTHROCYTE MATURATION FACTOR, BIOTIN, AND OTHER VITAMINS FOR THE YOUNG PIG. T. J. Cunha, R. W. Colby, L. K. Bustad and C. E. Lindley, *State College of Washington.*

A basal purified ration containing sucrose, casein, lard, minerals, A, D, E, K, C, and the 6 B-complex vitamins (thiamine, riboflavin, niacin, pyridoxine, pantothenic acid, and choline) was used. The following rations were fed: Basal, Basal+sulfasuxidine, Basal+sulfasuxidine+folic acid, Basal+sulfasuxidine+E.M.F., Basal+sulfasuxidine+folic acid+biotin, Basal+10% alfalfa, Basal minus pantothenic acid, and Basal minus pantothenic acid+biotin. After 86 days on experiment a folic acid antagonist was added to half the pigs fed sulfasuxidine. The addition of sulfasuxidine to the basal ration for 86 days was unsuccessful in producing a folic acid deficiency. The effect of adding a folic acid antagonist to the ration will be reported on. The addition of folic acid or an anti-pernicious anemia liver extract (E.M.F.) to the basal ration+sulfasuxidine resulted in biotin deficiency symptoms showing up much sooner and developing more severely than where the Basal+sulfasuxidine alone was fed. The addition of biotin to a pantothenic acid deficient ration resulted in pantothenic acid deficiency symptoms showing up sooner. Data will be reported on weight gains, efficiency of feed utilization, deficiency symptoms, and hemoglobin and other blood components observed in all lots of pigs.

COPPER METABOLISM WITH RELATION TO ALKALINE BLOOD PHOSPHATASE AND BLOOD ASCORBIC ACID. George K. Davis and Harry Hannan, Jr., *Florida Agricultural Experiment Station.*

In studies with copper deficient Devon cattle, it was observed that the alkaline blood phosphatase values increased as copper values decreased. Paralleling the increased phosphatase values, the blood inorganic phosphorous values rose from below 6.0 mg. percent to over 12.0 mg. percent. Accompanying this rise, the bones became brittle and in young animals many symptoms of ascorbic acid deficiency were present. Blood ascorbic acid changes have not been sufficiently marked to relate them to the changes observed in the animals: Copper administration quickly restored the phosphatase and blood inorganic phosphorous values to normal.

PRELIMINARY STUDIES ON SUPPLEMENTING A PURIFIED RATION FOR BROOD SOWS WITH FOLIC ACID, BIOTIN, INOSITOL, PABA, FISH MEAL AND ALFALFA MEAL. M. E. Ensminger, R. F. Johnson and T. J. Cunha, *State College of Washington.*

Fifteen gilts were used in this trial. The effects of adding folic acid alone and folic acid, biotin, p-aminobenzoic acid and inositol to a basal purified ration were studied. Alfalfa and

fish meal were used as a source of an unknown factor or factors. The purified basal ration used was composed of sucrose, casein, lard, minerals, A, D, E, K, C, and the 6 B-complex vitamins thiamine, riboflavin, niacin, pyridoxine, pantothenic acid and choline. The rations fed were as follows: Lot I, Basal; Lot II, Basal+pteroylglutamic acid; Lot III, Basal+pteroyglutamic acid, biotin, inositol and PABA; Lot IV, Basal+15% dehydrated alfalfa meal; and Lot V, Basal+5% fish meal. In lots IV and V the amount of casein used was decreased to compensate for the protein content of the alfalfa meal and fish meal added, thus equalizing the total protein content in all rations. Data will be reported on litter size, death losses, weaning weights, loss of weight by sows during lactation, and other pertinent information obtained.

THE EFFECTS OF SOYA-LECITHIN ON THE ABSORPTION AND UTILIZATION OF VITAMIN A. G. C. Esh, T. S. Sutton, J. W. Hibbs and W. E. Krauss, *Ohio State University and Ohio Agricultural Experiment Station.*

Four groups of dairy cows, 8 to a group, were fed: (I) herd ration; (II) herd ration+10 gms commercial soya lecithin; (III) herd ration+one million I.U. of vitamin A, and (IV) herd ration+one million I.U. of vitamin A+10 gms. of commercial soya lecithin daily for a period beginning 4 weeks before and continuing until one week postpartum. Assays of blood plasma vitamin A and carotene; vitamin A, carotene and lecithin in milk were made at intervals up to 21 days postpartum. Liver vitamin A of 10 new-born calves from differently treated dams was also determined. The plasma-vitamin A level in the group I cows fell almost to the half of the normal level postpartum, while the level in groups III and IV remained fairly high, group IV being the highest. At 21 days postpartum the vitamin A levels in the blood of group IV was also the highest. The vitamin A in the colostrum of group III was almost double that of the control group and in group IV almost 4 times that of the control group. Lecithin also was highest in the milk of group IV cows. The highest level of vitamin and lecithin was maintained in the milk of group IV 21 days postpartum. The total liver storage vitamin A in the new-born calves from the control group was negligible; about 6000 micrograms in vitamin A supplemented group and about 12,000 in the calves from the vitamin A+lecithin supplemented cows. Three groups of 6 calves each were fed from birth to 7 days of age as follows: (I) colostrum, (II) skimmilk+25,000–35,000 I.U. vitamin A, (III) skimmilk+25,000–35,000 I.U. vitamin A+3–4 gms of lecithin. Every calf in group II developed scours from the 3rd day and died on the 7th day, while all the calves in groups I and III grew well with slight evidence of digestive disturbance.

THE FEEDING OF SULPHUR IN LAMB FATTENING RATIONS. A. Lamar Esplin, A. W. Deem, W. E. Connell and Floyd Cross, *Colorado A. & M. College.*

Two years of sulphur feeding are reported as a control of death loss from enterotoxemia. In 1945–46, four lots of 500 lambs were fed. Two lots were self-fed and two lots hand-fed grain with alfalfa hay fed through panels. One self-fed and one hand-fed lot were fed inorganic sulphur in the amount of 2 per cent of the grain ration. The second year, eight lots of 135 lambs were self-fed to determine desirable levels of sulphur. The levels fed were $\frac{3}{4}$ oz., $\frac{1}{2}$ oz., and $\frac{1}{4}$ oz. sulphur per lamb per day and were replicated. The death loss from this disease was 1 percent or less for self-fed and hand-fed lambs when sulphur made up 2% of the grain ration compared to 8% for self-fed and 6% for hand-fed lots when sulphur was not fed. Grain consumption and gains were considerably less when this amount of sulphur was fed. The death loss was less than 1%, 3%, and $6\frac{1}{2}$% when sulphur was fed $\frac{3}{4}$ oz., $\frac{1}{2}$ oz., and $\frac{1}{4}$ oz. per lamb per day respectively compared to $11\frac{1}{4}$% when sulphur was not fed. The feeding of sulphur slightly lowered the grain consumption, the rate of gain, and the efficiency of the gain but did not influence carcass grade, or flavor of the meat. It is suggested that sulphur be fed in the amount of $\frac{3}{4}$ oz. per lamb per day when self-fed with a grain ration. There is no explanation offered as to the manner in which the sulphur acts.

SOME FACTORS AFFECTING THE VITAMIN A AND C LEVELS IN PIGS. BLOOD. R. H. Grummer, C. K. Whitehair, P. H. Phillips and G. Bohstedt, *University of Wisconsin.*

Plasma vitamin A and C determinations were made on a herd of 94 suckling pigs that

were suffering from a severe digestive disturbance. The pigs were divided into three groups according to their condition and the severity of their symptoms. The three groups were classified thrifty, unthrifty, and moribund. The respective average vitamin values were 0.27γ, 0.18γ, and 0.07γ vitamin A per 100 cc. of blood plasma, and 0.85 mg., 0.66 mg., and 0.48 mg. vitamin C per 100 cc. of blood plasma. To measure the influence of the plane of nutrition on the vitamin A and C plasma levels two groups of weanling pigs were fed two different rations. The one ration contained a large amount of yellow corn with a limited amount of plant protein and no animal protein. The other ration was a well balanced ration containing both animal and plant protein. The blood plasma from the pigs fed the well balanced ration contained 0.1 mg. more vitamin C but no more vitamin A than the pigs receiving the poorer ration. The addition of 20 percent lactose and chlorobutanol (10 gr./100 lbs. feed) to a basal ration of corn, soybean oil meal, and ground alfalfa hay increased the vitamin A and C plasma levels. Feeding 100 mg. of crystalline vitamin C to newborn pigs immediately after birth increased the vitamin C plasma level more than 2.0 mg. Taking the pigs away from the mother and feeding them heated cow's milk produced an average decrease of 0.15 mg. in the plasma vitamin C level.

THE PROTEIN REQUIREMENTS OF GROWING FOXES. Lorin E. Harris, Charles F. Bassett, Leonard M. Llewellyn and John K. Loosli, *United States Department of Agriculture and Cornell University, cooperating.*

Diets as adequate as knowledge permits were fed to growing foxes at the following percentage levels of protein on a dry basis: 13, 16, 19, 22, 25, 28, 34, and 40. Fox pups were fed in such a way as to evaluate the protein requirements from 50 days of age (weaning time) to 161 days of age (end of fastest growing period) and from 161 days of age to 262 days of age (pelting time). Carcass analyses and balance studies were conducted during the above period. The animals were small in size on the lower protein diets. The minimum protein requirement (dry basis) for fox pups 50 to 161 days of age lies between 22% and 25%, and for 161 to 259 days of age it lies between 19% and 22%. In practice one should feed diets containing 25% to 34%, and 19% to 25% respectively.

RAISING NEW-BORN PIGS TO WEANING AGE ON A "SYNTHETIC" DIET, WITH ATTEMPT TO PRODUCE A PTEROYLGLUTAMIC ACID DEFICIENCY. B. Connor Johnson, Marian F. James and J. L. Krider, *University of Illinois.*

Two groups of ten baby Duroc-Jersey pigs have been raised to weaning age on a "synthetic" diet composed of casein, cerelose, lard, salts and vitamin. This ration was made up in water with the lard homogenized in to simulate milk. In order to inhibit intestinal synthesis of pteroylglutamic acid or unknown factors all animals received 3 gms. (2 % dry basis) of sulfathalidine per liter of milk. The first group was started on the synthetic milk at 2 weeks of age and was carried for 6 weeks. These pigs averaged 2981 gms. at the beginning of the experiment and 14,830 at the end. This is a gain of 290 gms. per day. The second group was started on experiment at 4 days of age and was kept on for 7 weeks. Their weight averaged 1986 gms. at the start and 16,120 gms. at the close of the experiment. This is a gain of 288.4 gms. per day. Pteroylglutamic acid was omitted from the diet of 5 of the pigs in each of these groups in attempt to produce a deficiency of PGA in the baby pig. However, there was practically no difference in growth of the PGA free group as compared to the animals receiving PGA. The deficient groups showed no blood pathology of any kind, however, they did show definitely lighter colored hair coats.

CRYSTALLINE OR CONCENTRATES OF B-VITAMINS SUPPLEMENT A CORN-SOYBEAN MEAL RATION FOR WEANLING PIGS IN DRYLOT. J. L. Krider, D. E. Becker and W. E. Carroll, *University of Illinois.*

Weanling pigs from sows kept in drylot were fed to weights of 75 pounds. In test A, the basal ration was 63.5% ground yellow corn, 34% expeller soybean meal, 0.5% fortified vitamin A and D oil, and 2% complex mineral mixture. In tests B and C, 15% of wheat flour

middlings replaced part of the corn and soybean meal. All rations contained 20% crude protein. The supplements fed and the average daily gains in pounds were as follows: test A (1) basal (0.30); (2) basal+6 crystalline B-vitamins (B_1, B_2, B_6, niacin, pantothenic acid, and choline) (0.94); (3) same as (2) +10% dehydrated alfalfa meal (0.80); and (4) same as (2) +0.5 mg. folic acid per pound of ration (0.89); test B (1) basal+6 crystalline B-vitamins (0.98); (2) same as (1) +10% dehydrated alfalfa meal (0.90); (3) same as (1) +1.5% AB liver extract (1.08); and (4) same as (1) +.24 crystalline folic acid per pound of ration (1.05); test C (1) basal+6 crystalline B-vitamins (1.12); (2) same as (1) +pyracin, PAB, inositol, biotin, alpha tocopherol and vitamin K (1.06); (3) same as (1)+10% dehydrated alfalfa meal (1.00); (4) same as (1) +1.5 AB liver extract (1.22); (5) same as (1)+folic acid concentrate to supply 0.24 mg. of folic acid per pound of diet (1.09); and (6) same as (1)+5% Cerogras (1.11). Most of the basal pigs in test A became emaciated, listless, unthrifty, had rough coats, and severe diarrhea and 27% died. Blood of survivors averaged 7.0 grams of hemoglobin per 100 cc. and 5.1 million red blood corpuscles per ccm. Blood from the other groups had hemoglobin values of 10.0, 9.8, and 9.8 grams, and red blood corpuscle counts of 6.9, 6.7, and 7.1 million, respectively. The liver extract apparently supplied a growth factor(s) essential for optimum gains of pigs.

THE USE OF DEHYDRATED ALFALFA MEAL AND CERTAIN BY-PRODUCTS OF THE FISH AND DISTILLING INDUSTRIES IN DRYLOT RATIONS OF WEANLING PIGS. J. L. Krider, S. W. Terrill, D. E. Becker and W. E. Carroll, *University of Illinois.*

Two tests were made of the supplementary value of dehydrated alfalfa meal, condensed sardine fish solubles, and of combinations of alfalfa meal, fish solubles, menhaden fish meal, and dried corn distillers' solubles for pigs from weaning to 100 pounds in drylot. The basal diet was composed of 67% ground yellow corn, 6% meat scraps, 25.5% expeller soybean meal and 0.5% each of limestone, iodized salt and fortified vitamin A and D oil. All rations contained 20% crude protein. Pigs fed 4% alfalfa meal grew faster and required 13% less feed per 100 pounds gain than those fed the basal diet. With 10% alfalfa meal, gains were more rapid and economical than with 4% alfalfa meal. The combination of 4% alfalfa meal and 6% distillers' solubles was not improved by adding 3% menhaden fish meal. Two percent of fish solubles produced as well as 4% of this product and results at both levels equalled those from the addition of 10% alfalfa meal. Four percent of fish solubles produced as rapid gains as the combination of 6% alfalfa meal and 4% fish solubles. In the third test, five lots of weanling pigs were fed in drylot to 75 pounds to evaluate semi-solid fish and fish solubles. The basal ration (20% crude protein) was composed of 60% ground yellow corn, 33% expeller soybean meal, 5% dehydrated alfalfa meal, 2% of minerals, and irradiated yeast. The addition of 3% or 5% of semi-solid fish from Cod and Haddock, 3% of semi-solid Red Fish, or 2% sardine fish solubles to the basal ration increased gains slightly. The results with various fish by-products were similar.

MAGNESIUM DEFICIENCY IN RABBITS. H. O. Kunkel and P. B. Pearson, *Agricultural and Mechanical College of Texas.*

A purified basal diet has been developed for rabbits which is adequate in all known factors except magnesium. Feeding New Zealand White rabbits diets containing insufficient magnesium results in a symptom complex of hyperirritability, hypomagnesaemia, retardation or early cessation of growth, convulsive seizures, and death. Vasodilatation was not observed. Convulsive seizures induced by artificial auditory stimulus did not terminate fatally. Death occurred only after spontaneous convulsive seizures which generally were not preceded by the incoordinated running about which always preceded the induced seizures. When the diet contained 60 p.p.m. magnesium, retardation of growth occurred between the second and eighth week of experiment. Extreme emaciation was apparent in all animals maintained for an extended period on the deficient diet. In the later stages of deficiency rabbits became lethargic with little response to physical or auditory stimulus. The magnesium content of the blood, as determined by an improved method, continued to decrease throughout the entire experimental period reaching levels less than half of those of rabbits fed 450 p.p.m. magnesium in

the diet. Minimal levels in plasma (1.0 mg. of magnesium per 100 ml. as compared with control levels of 1.3 to 2.2 mg. per 100 ml.) were reached by the sixth week and remained at this level during the rest of the period. Data are available on the quantitative requirement of rabbits for magnesium and the effect of the calcium content of the diet upon this requirement.

FURTHER STUDIES ON THE RELATIONSHIP OF NIACIN AND PROTEIN IN SWINE NUTRITION. R. W. Luecke, W. N. McMillen and F. Thorp, Jr., *Michigan State College.*

Previous studies have shown that good growth resulted when tryptophane was added as a supplement to a low protein corn ration. However, all symptoms of niacin deficiency were not prevented with daily supplements of 200 mg. of d, l tryptophane per pig. In the present experiments a basal ration containing 14 percent protein made up of corn, 87; casein, 5.5; soybean meal, 5.5; mineral, 2; and liberal amounts of thiamine, riboflavin, pantothenic acid and pyridoxine were fed to a group of weanling pigs whose average weight was 22 pounds. In addition each pig received daily supplements of 1 gm. of d, l tryptophane. The growth of the pigs in this lot was not superior to that of the pigs which received the lower levels of tryptophane, but no symptoms of niacin deficiency were observed with the higher levels fed. The average daily gain for the pigs in this lot was 0.86 pounds per pig. When the casein content of the above ration was increased to 25 percent at the expense of the corn the animals grew very well and showed no symptoms of niacin deficiency. The pigs in this lot averaged 1.10 pounds gain in body weight per pig per day. The incorporation of 10 percent distillers' dried solubles in the above ration gave good growth and prevented symptoms of niacin deficiency from appearing. The average daily gain for the pigs in this lot was 0.71 pounds per pig. The feeding of 800 mg. of d, l tryptophane to niacin deficient pigs was not as effective as 100 mg. doses of niacin in the cure of the deficiency.

STUDIES OF THE EFFECT OF PHOSPHATE FERTILIZATION ON THE COMPOSITION AND NUTRITIVE VALUE OFCERTAIN FORAGES FOR SHEEP. G. Matrone, R. L. Lovvorn, W. J. Peterson, J. E. Foster, F. H. Smith and J. A. Weybrew, *U. S. Plant, Soil, and Nutrition Laboratory, and North Carolina State College.*

Phosphate fertilization of soybean hays grown on a Bladen type soil extremely low in phosphorus produced no significant change in composition as measured by standard feedingstuffs analysis, which included calcium and phosphorus. This was also true of the Bull grass contaminant. Fattening trials and digestibility studies with lambs using soybean hay for roughage and raw soybeans for concentrate gave no significant differences either in weight gains or apparent digestibilities between feeds fertilized with phosphate and those not fertilized with phosphate. When cerelose replaced soybeans as the concentrate, lambs which received soybean hay fertilized with phosphate gained an average of 0.282 lb. daily per lamb as compared to 0.192 lb. for the non-phosphate group. This difference approached significance at the 5% level. Digestibility studies using soybean hay alone as well as with cerelose as the concentrate gave slightly higher digestibilities of all standard feed nutrients for phosphate-fertilized hays as compared to hays not fertilized with phosphate. Only ether extract, however, approached significance at the 5% level. Serum phosphate values of lambs fed phosphate-fertilized hay plus sugar were higher than those of lambs receiving non-phosphated hay plus sugar. Generalizations on the influence of fertilization on the nutritive value of plants for animals are not warranted at this stage of the investigations.

RAT AND PIG FEEDING TRIALS WITH GRAINS OF DIFFERENT PROTEIN CONTENT. L. W. McElroy and W. Lobay, *University of Alberta.*

Feeding trials were conducted to study the effect that variations in the protein content of grains may have upon growth when rations composed mainly of cereal grains are fed to weanling rats and pigs. Samples of grain containing less than 10% protein were arbitrarily classified as "low," those containing 12% to 13% as "medium" and those containing 16% or more as "high" protein grains. When such grains were fed to rats in rations in which

grain constituted the only source of protein, marked differences in growth response were observed. The results of a pig feeding trial showed that when a mixture of oats and barley constituted the only source of protein during the period from 30 lbs. to 200 lbs. live weight, the group fed high protein grains made an average daily gain of 1.07 lbs. and required 380 lbs. of feed per 100 lbs. gain. The corresponding figures for groups fed medium and low protein grains were 0.97, 405 and 0.87, 486 lbs., respectively. Comparison of these results with those obtained with groups supplemented with an arbitrary level of a mixed protein supplement without regard to the protein content of the grain in the basal ration, showed that protein supplementation resulted in increased rates of gain in all cases and that the reduction in total feed required per 100 lbs. gain, attributable to the use of protein supplement, was 129 lbs., 66 lbs., or 31 lbs. depending upon whether low, medium or high protein grains were used.

THE NUTRITIVE VALUE OF BARN-DRIED HAY FOR DAIRY COWS. S. H. Morrison and K. L. Turk, *Cornell University.*

The results of three years' (1944, 1945, and 1946) work are reported comparing the feeding value of barn-dried hay, field-cured hay stored loose, and field-cured windrow-baled hay cut from the same field. The hay was fed as the only roughage, and concentrates were fed at the same rate to each group of cows. Thirty-six Holstein cows have been used in these trials. The average daily consumption of the various kinds of hay per cow was: barn-dried, 32.2 lbs.; field-cured loose, 32.3 lbs.; and windrow-baled, 31.3 lbs. The average daily 4% fat-corrected milk production on the barn-dried was 31.6 lbs.; field-cured loose, 31.4 lbs.; and windrow-baled, 32.0 lbs. The hays were sampled at regular intervals for carotene determination and federal grading. At the time of feeding the barn-dried hay has averaged approximately one grade higher than the other two types of hay. However, the carotene content of the barn-dried hay at the time of feeding was not enough greater than either the windrow-baled or field-cured loose hays to be of much practical significance. The carotene contents of the various hays expressed as micrograms per gram of dry matter were: barn-dried, 11.6; field-cured loose, 7.5; and windrow-baled, 7.1. The barn-dried hay had no more protein than the other two types of hay. The live weights of the cows were equally well maintained on the three kinds of hay.

BLOOD CALCIUM AND PHOSPHORUS LEVELS IN RANGE CATTLE. A. L. Moxon, Twila M. Paulsen and L. E. Johnson, *South Dakota Agricultural Experiment Station.*

Blood samples were taken from 88 head of range cattle over a period of 5 years for plasma calcium and plasma inorganic phosphorus determinations. These cattle were on controller summer grazing and wintering experiments. Forty head were on an Experimental ranch in Lyman Co. and 48 head were on the Range Field Station at Cottonwood in Jackson Co. The cattle at Cottonwood were bled in early spring, midsummer and late fall in 1942, '43, '45, and '46. The cattle in Lyman Co. were bled on seventeen occasions between Apr. 1, 1942 and Jan. 24, 1945. Phosphorus showed a range of 1.19 to 9.57 mg. per 100 ml. plasma with a mean value of 4.77 mg./100 ml. in samples from cattle in Lyman Co. Calcium values ranged from 4.8 to 19.8 mg. per 100 ml. plasma with a mean value of 9.9 mg./100 ml. Levels for Cottonwood cattle were similar. Calcium and phosphorus levels as related to season and management practices will be discussed.

EFFECT OF THIOURACIL AND PROTAMONE ON GROWING SWINE. M. E. Muhrer, D. R. Warner, Z. Palmer and A. G. Hogan, *University of Missouri.*

Four crossbred pigs received the basal ration and eight similar pigs received the same ration with the addition of 0.05 and 0.1% of thiouracil. In a 28 day period of ad libitum feeding the pigs that received 0.1% thiouracil required 24.4% less feed per unit gain in weight than did the controls. Six of the pigs were slaughtered, and analyzed for water, fat, protein and ash. The thiouracil-fed pigs contained about 3% more water and about 3% less fat than did the controls. The appearance of the live animals indicated that the thiouracil-fed pigs contained the larger percentage of fat but that was not the case. They actually contained

about 3% less fat and 3% more water than did the controls. Samples of fatty tissue (leaf lard) and of muscle (lean of loin) from the thiouracil-fed pigs, both contained a lower percentage of fat than did the controls. The lean of loin from the thiouracil-fed pigs contained 71.9% water, 5.7% fat, 21.8% protein and 1.09% ash. The lean of loin from the controls contained 69.1% water, 8.2% fat, 21.9% protein and 1.11% ash. The dressing percentage of the two groups was the same, 73%. In preliminary trials protamone-fed pigs did not gain as rapidly or as economically as either the control or thiouracil-fed pigs.

THE EFFECT OF RATION ON CERTAIN VITAMIN CONCENTRATIONS IN THE BLOOD, LIVER, AND MILK OF EWES AND THEIR LAMBS. A. L. Pope, W. C. Weir, G. Bohstedt and P. H. Phillips, *University of Wisconsin.*

In an attempt to determine if ewes on pasture during the summer could successfully complete gestation and lactation on a very low carotene ration, a group of ewes were fed the following ration for two successive winters: Oat straw, oats, soybean oil meal, and $CaCO_3$. A control group was fed alfalfa hay and oats. During the second season additional ewes were added to the low carotene group and given 25,000 I.U. of vitamin A weekly. Blood plasma vitamins A and C and hemoglobin were determined periodically on the ewes and their lambs, and vitamins A and C on ewes' milk. Part of the ewes and their lambs were sacrificed at 8 weeks after lambing, and the remainder after 1 month on pasture, to determine liver vitamin A reserves. The results show that the straw ewes did not maintain their weight as well as the hay ewes. There was no appreciable difference in the growth of single lambs, but in the twins the hay group was markedly superior. Although there was no significant difference in the vitamin A concentration of the milk, the blood plasma level of both ewes and lambs was higher in the hay group. Vitamin A administration did not increase the blood plasma of the ewes or their lambs over the straw group. However, liver analyses of the ewes show the straw ewe reserves were much lower than those of the hay ewes, with the ewes receiving vitamin A, intermediate. Hemoglobin at birth in all lambs was high and decreased sharply the following week.

EFFECT OF VARYING THE ENERGY SOURCE ON ACID PRODUCTION BY SOME MIXED CULTURES OF SILAGE ORGANISMS. R. L. Salsbury and C. B. Bender, *Rutgers University.*

Water extracts obtained from two molasses silages at various stages of fermentation were inoculated into media each of which contained a different carbohydrate as energy source. Production of acid was measured by titration of the cultures after four days incubation at thirty degrees Centigrade. Over the period of the experiment, differences were obtained in the average production of acid on the different media. Generally, arabinose gave greater acid production than xylose, sucrose greater than lactose, and levulose and dextrose greater than galactose. The alcohols, glycerol, mannitol and sorbitol showed lower acid production than the foregoing, and mannitol and sorbitol generally produced more acid than did glycerol. The polysaccharides inulin, dextrin, and soluble starch were fermented to produce approximately similar amounts of acid, no definite preference of carbohydrate being apparent here.

A STATISTICAL STUDY OF DATA ON APPARENT DIGESTIBILITY OF HAYS BY CATTLE. Burch H. Schneider, Helen M. Pavlech and Henry L. Lucas, *West Virginia University and North Carolina State College.*

Data from 382 digestion trials with cattle on 13 kinds of hay and published by 64 authors were analyzed statistically. There were significant differences between the different hays in digestibility of all nutrients. There were significant differences between protein and N-F.E. composition of the hays studied, but the variation within each kind of hay was so great that the differences in percentages of crude fiber and fat between the different kinds of hay were not significant. Co-variance adjustments of the digestion coefficients and of T.D.N. for chemical composition did not remove the significant differences for digestibility that exist between hays or between investigators. Multiple regression studies showed that there were significant relationships between the chemical analysis and the digestion coefficients of nu-

trients. Thus the proximate composition can be used to predict the digestibilities of nutrients. These predictions are more accurate than fixed average coefficients when applied to a sample or to an average composition of a feed. A different prediction equation is needed for each kind of hay, as follows: $K = C_K + 1.81\ J_0 + 3.38\ P_0$ and $R = C_R + 1.13\ J_0 + 0.58\ N_0$ in which K and R are the predicted values and C_K and C_R the constants for the digestion coefficient of crude protein and the T.D.N., respectively. J_0, N_0, and P_0 are the percentages of protein, N-F.E. and fat in a sample or average. The constants C_K and C_R, for a few of the hays are as follows: alfalfa 34, 14; alfalfa clover timothy mixed 26, 13; red clover 24, 17; clover grass mixed 28, 17; soybean 30, 15; timothy 24, 17.

THE VALUE OF DEHYDRATED SWEET POTATOES AS A CARBOHYDRATE FEED FOR FATTENING STEERS. B. L. Southwell and W. H. Black, *Georgia Coastal Plain Experiment Station and United States Department of Agriculture.*

Sweet potatoes grow well in the lower southeast, are relatively more productive than corn and offer possibilities as an abundant and cheap source of carbohydrate feed. The mature sweet potatoes are shredded for drying. They are dried either by spreading in a thin layer on a hard surface for two days or in artificial dehydraters. The dried product stores easier in the lower Southeast than shelled corn. In dry lot steer feeding tests of 140 days length dehydrated sweet potatoes proved less palatable and more laxative than corn when it replaced all the corn in a grain mixture of 6 parts cracked shelled corn and 1 part cottonseed meal. A grain mixture of 3 parts dehydrated sweet potatoes, 3 parts cracked shelled corn and 1 part cotton seed meal gave slightly higher daily gains than corn and cottonseed meal. The steers fed the mixture of potatoes and corn ate somewhat more feed, showed a little better finish and sold for a little higher price than those on the other grain mixtures. Ground snapped corn proved somewhat superior to dehydrated sweet potatoes as a steer feed when used as the only carbohydrate. The sweet potatoes used in these tests (Porto Rico variety) produced a slightly yellow fat in the beef carcasses.

STUDIES ON THE VALUE OF WHEY PRODUCTS IN EARLY CALF NUTRITION. R. F. Van Poucke, F. W. Hill, R. A. Zuercher and N. E. Rodgers, *Western Condensing Company.*

Experiments were conducted over a two year period to determine the feasibility of substituting a whey product for whole milk in early calf nutrition. Holstein calves, 3–4 days of age, were compared on the following treatments during a 112 day period: I. Whey product plus commercial calf meal and, II. Whole milk plus commercial calf meal. Mixed hay and salt were fed ad libitum throughout the trials. The average daily gains were 1.84 and 1.81 pounds, with 2.53 and 2.21 pounds of milk solids plus calf meal required per pound of gain, respectively. During the trial 84.5 and 147.3 pounds of milk solids were consumed per calf. These observations indicated that whey product can successfully supplant whole milk in early calf nutrition and promoted trials comparing the value of a 20% vegetable protein calf meal with a 20% protein meal containing 5% animal protein when fed in combination with the whey product. Average daily gains were 1.49 and 1.45 pounds respectively, with 2.41 pounds of milk solids plus calf meal required per pound of gain. Amounts of 114.8 and 119.9 pounds of milk solids were consumed per calf. Combined results of all tests indicate that milk solids are associated with the efficiency of utilization of feed for early growth of calves. Whey product in combination with vegetable protein calf meal produced gains as efficiently as in combination with animal protein meal. Mortality in all experiments was less than 2%.

THE EFFECT OF THE PLANE OF NUTRITION AND ASSOCIATION ON THE DIGESTIBILITY OF FOOD STUFFS BY RUMINANTS. Cyril J. Watson, *Canadian Dept. of Agriculture.*

The effects of the plane of nutrition and association on the digestibility of feedstuffs by ruminants have been studied over a period of fifteen years. For both factors the investigation included roughages, succulent feeds, grains and concentrates. They were fed singly and in various combinations. It was concluded that for most feedstuffs these two factors either had no effect upon digestibility or, where differences existed, they were of small magnitude.

THE EFFECT OF HEMOPOIETIC DIETARY FACTORS UPON INTERNAL PARASITE INFECTION IN SHEEP. W. C. Weir, T. L. Bahler, M. F. Badr, A. L. Pope, C. A. Herrick, G. Bohstedt and P. H. Phillips, *University of Wisconsin.*

Four lots of grade Shropshire ewes (3 ewes per lot 1946, 8 per lot 1947) were fed as follows: Lot I—Basal of 4 lb. fair to poor mixed legume and grass hay, 0.25 lb. corn, and iodized salt; Lot II—Basal plus 1% bone meal in the grain, and mineralized salt; Lot III—Basal plus 0.25 lb. soybean oil meal; and Lot IV—Basal plus 0.25 lb. soybean oil meal, 1% bone meal in the grain, and mineralized salt. The mineralized salt contained $CoSO_4$, $CuSO_4$, $MnSO_4$, Fe_2O_3, and KI. The corn ration was increased to 0.5 lb. for Lots I and II, and to 0.75 lb. for Lots III and IV on May 24, 1946, and immediately after lambing in 1947. Lambs were creep fed the ewe grain mixture ad lib. April born lambs from these ewes were given a drench of 4,000 larvae of the common stomach worm (*Hemonchus contortus*) on June 20, 1946, and July 14, 1947. About 6 weeks later a larger drench (40,000 in 1946, 15,000 to 18,000 in 1947) was given. Data will be presented showing the effect of the ration and the worm infections on growth, feed consumption, fecal egg count, post-mortem worm count, hemoglobin, blood plasma vitamins A and C, plasma protein, and inorganic phosphorus of these lambs. Results of 1946 experiment and preliminary observations for 1947 indicate that lambs receiving these minerals passed worm eggs earlier and had larger numbers of worms at autopsy. The higher protein level seems to exert a protective effect.

NUTRITION STUDIES WITH SWINE. I. SUPPLEMENTED MILK DIETS FOR YOUNG PIGS IN CAGES. J. A. Weybrew, H. A. Stewart, W. J. Peterson and Gennard Matrone, *N. C. Agricultural Experiment Station and U. S. Plant, Soil, and Nutr. Laboratory.*

Baby pigs have been successfully raised in screen-floored cages from 1 day of age to normal weaning age of 8 weeks on milk diets supplemented with minerals and cod-liver oil. Three essentially whole milk diets were compared: Diet A, evaporated milk; Diet B, reconstituted non-fat milk solids plus butter; and Diet C, reconstituted whole milk powder. Creamery butter supplemented the skim milk diet in the ratio of 1 part butter to 3 parts skim milk solids. The solids content of the milk slurries ranged from approximately 17 wt.-vol. percent at the start to 40 percent (except for Diet A, which never exceeded the solids content of the evaporated milk) for the last three weeks of the trial. In general, the pigs made excellent gains on all diets during the first 5 weeks. At 8 weeks, the mean weights were 35.1 ± 3.0, 46.8 ± 2.1 and 48.6 ± 1.4 pounds for the three diets, respectively. On diets permitting more rapid gains, the pigs performed more uniformly; the respective coefficients of variation at 8 weeks were 22.8 percent, 10.1 percent, and 8.2 percent. At weaning age, the hand-fed pigs on an average weighed 9.6 pounds more than a comparable number of similar pigs that had been suckled by their dams on good pasture with access to a self-feeder. Mortality during the experiment was 12½ percent.

AMINO ACID SUPPLEMENTATION OF CORN FOR SMALL PIGS. C. K. Whitehair, R. H. Grummer, G. Bohstedt and P. H. Phillips, *University of Wisconsin.*

Previous experiments have shown the value of using small grains such as oats and wheat in place of corn for young pigs suffering from chronic symptoms of digestive disturbances or enteritis. Further work on this problem indicates that at least part of the growth promoting ability of the small grains for this condition in contrast to corn is due to the low amounts of the amino acids, tryptophane and lysine in corn. The average daily gain for pigs affected with chronic symptoms of enteritis on a corn basal ration supplemented with soybean oil meal was 0.13 lb. for a 4-week growth period. Pigs showing the same clinical symptoms as the controls gained at the rate of 0.44 lb. daily on an oats-wheat basal ration also supplemented with soybean oil meal. When the corn basal ration was supplemented with tryptophane and lysine, the daily growth rate was 0.40 lb. daily or almost equal to that on the oats-wheat ration. A 2 percent salt mixture containing all the minerals needed in animal nutrition was added to the corn basal ration and produced a gaily gain rate of 0.22 lb. or some improvement over the controls. All 4 rations contained about the same amount of protein on a percentage basis. Growth rates, tryptophane and nicotinic acid values are given.

Pasture and Range Section

M. L. Baker, *Chairman*

EFFECT OF WINTER SUPPLEMENTATION ON SUBSEQUENT GAINS OF BEEF STEERS ON GRASS AND IN THE FATTENING LOT. W. E. Connell, S. S. Wheeler and R. C. Tom, *Colorado A. & M. College and Experiment Station.*

Three years experiments were conducted in Northeastern Colorado to determine the effect of adding one pound of cottonseed meal or soybean meal to the basal wintering ration of sorghum roughage for steer calves on their current and subsequent gains. A comparison was also made between cane silage and chopped cane fodder for wintering calves. The addition of the protein supplement to the wintering ration stimulated appetite and added 85 pounds per head to the gains. The extra feed required to produce this gain cost $6.65 or 7.8 cents per pound added gain. At the end of the six months summer grazing, the spread in gains was reduced to 37 pounds, increasing its cost per pound to 18.1 cents, while by the end of the following fattening period the extra gain was narrowed to 30 pounds and cost 22.3 cents per pound. Based on Morrison's energy tables and expressed in terms of feed replacement, the value of the protein supplement fed during the winter was increased seven times. However, this replacement value was lost by the end of the summer grazing period. From a practical feeding standpoint, it would pay to add a protein supplement to the wintering ration if the calves were sold at the end of this period, but its value is questionable if the calves are carried on through the grazing and fattening periods. Cane silage and chopped cane fodder, considered on a dry matter basis, were equal in feed value.

PRODUCING MEAT ON WHEAT PASTURE WITH AND WITHOUT SUPPLEMENTAL FEEDING. Rufus F. Cox, *Kansas Agricultural Experiment Station.*

Repeated tests show little advantage for feeding grain, roughage, protein supplement or ground limestone to lambs on wheat pasture, unless digestive trouble is being experienced. Dry roughage helps to prevent digestive disorders among lambs on wheat pasture. Lambs given access to a Milo stalk field (combined) while on wheat pasture gained more than those receiving wheat pasture alone. Lambs were grazed on wheat which had 125 pounds per acre of treble superphosphate applied at the time of sowing. A very slight increase in gain accompanied the grazing of the fertilized wheat. In this case, however, the soil was not deficient in phosphorus in the first place. The blood of the lambs grazed on phosphated wheat pasture was nearly 20% higher in phosphorus but virtually no different in calcium and potassium content from the blood of lambs grazing unfertilized wheat. When lambs have access to good wheat pasture furnishing all the forage they will eat, all nutrients apparently are sufficient in amount to meet their needs, and in case of certain mineral elements, the supply is often three times the requirements.

USING PASTURE AND ROUGHAGE IN PRODUCING BEEF. A. J. Dyer, *University of Missouri.*

By making maximum use of good roughage in winter and good pasture in summer, less than 10 bushels of grain were required to develop choice weanling calves to 1150 pound 2-year-old steers carrying sufficient finish to top the St. Louis market on the date they were sold. In three successive trials, very similar results have been obtained. The three things essential for the success of this system of management are (1) well bred cattle, (2) an abundance of good roughage in winter, and (3) an abundance of good pasture in summer. Producing beef with very little grain fits well into pasture farming practiced in Missouri.

DIGESTIBILITY OF SOME PASTURE FORAGES BY STEERS AND WETHERS AS AFFECTED BY THE CHEMICAL COMPOSITION OF THE FORAGE. R. M. Forbes and W. P. Garrigus, *University of Kentucky.*

Six grade Hereford steers and fifteen wethers out of western ewes and by Southdown rams were used in these experiments. Four series of experiments were conducted with the

steers, each series consisting of a digestion trial run on one group of three steers at the same time that the remaining steers were on pasture and harnessed for fecal collection. The steers on digestion trial received fresh bluegrass clipped daily and similar in stage of maturity to bluegrass consumed by the group on pasture. The groups of steers were reversed in each succeeding series. Three additional digestion trials were conducted with the steers without comparable pasture trials. The wethers in groups of three were placed on different forages, and several alternating digestion and pasture trials were conducted with each group. Digestion coefficients were determined both by the usual method and by the lignin ratio technique of Ellis, Matrone and Maynard. Satisfactory agreement was obtained between coefficients determined by the two methods when experimental conditions were carefully controlled. The coefficient of digestibility of dry matter by the steers varied in a straight line relationship from 80% to 50% as the maturity of the forage increased, as indicated by progressive change in: (a) lignin content from 3.9% to 9.1% (dry basis), (b) crude fiber content from 22.1% to 30.0%, and (c) protein content from 18.8% to 12.9%. The digestibility of all feed constituents followed the pattern of dry matter digestibility. Comparison of dry-matter digestibility by all lambs on all forages with the composition of the forage resulted in high negative correlation with lignin content, but lower correlation with protein and crude fiber content.

AGE, WINTER GAIN AND GRAZING METHODS AS FACTORS IN STEER PRODUCTION FROM PASTURE. C. M. Kincaid, George W. Litton and R. E. Hunt, *Virginia Agricultural Experiment Station.*

Two ages (yearling and two-year old feeders), three winter feeding levels (maintenance, ½ pound and 1 pound per day liveweight gain, approximately) and different methods of grazing were compared in a factorial arrangement. On the average the older steers had ⅙ of a grade better carcasses and one percent higher dressing percent. Annual gain, carcass grade and dressing percent improved as winter gain increased. The regression of summer gain on winter gain from differences among feeding levels and from differences within subclasses were −0.69 and −0.42, respectively. The regression of fill during the first 24 hours on pasture on winter gain, estimated in 1946, yielded a regression coefficient of −0.19. When adjustment was made for differences in fill among feeding levels, the two estimates of regression of summer gain on winter gain were not greatly different. As acres of pasture per steer increased from 1.58 to 3.92 acres, average gains per acre of pasture decreased and average gains per steer increased. Because heavy grazing reduced the gains per steer and also reduced the length of the grazing season, an intermediate grazing rate (approximately 2.5 acres per steer) seemed to be the optimum when rainfall was about equal to or above the long time average. In one year (1944) with deficient rainfall in July and August, light grazing (3.67 acres per steer) produced significantly greater gains per steer than the intermediate rate.

A COMPARISON OF THE PRODUCTION FROM RANGE COWS AND YEARLING STEERS. J. H. Knox and Marvin Koger, *New Mexico Agricultural Experiment Station.*

For eleven years records of gains made by nearly 450 steers for 12 months after weaning have been kept along with records of the annual production of breeding cows on similar range. The average gain per head made by the steers equalled 85 percent of the average calf production from cows with a 90 percent calf crop. Since it was impractical to measure forage consumption directly in the extensive semi-desert pastures used, the amount of feed eaten was calculated from the estimated maintenance requirement and the energy content of the gain produced. By this method the forage consumption of yearling steers which weighed 429 pounds at weaning and 745 pounds a year later was calculated to be 65 percent of that of 950-pound breeding cows producing a 90 percent calf crop with calves weighing 424 pounds at weaning. The production by the steers per unit of feed consumed was calculated to be 132 percent of that of breeding cows under similar conditions. A drought of one year reduced the production from steers slightly more than cows during the current year, but the net result was favorable to the steers because of the lowered calf crop in the year following the drought.

COMPARISON OF VARIOUS METHODS OF USING IMPROVED PERMANENT PASTURES FOR FATTENING STEERS. J. I. Miller, F. B. Morrison and J. E. Briggs, *Cornell University.*

Two series of trials were conducted during the pasture seasons of 1944, 1945, and 1946. The pastures used had been plowed and seeded with proper fertilization in 1940 and at the time of the trials had a ground cover consisting of approximately 66 percent Kentucky bluegrass, 7 percent other grasses (mostly timothy and redtop) and 13 percent clovers (wild white and Ladino). In one series of trials yearling steers purchased in the spring, grazed on pasture alone, and sold in early October made an average daily gain of 1.32 lbs. They had the lowest cost per cwt. gain, the lowest selling price per cwt., and the lowest net return of the methods of feeding studied. Similar steers hand-fed a total of approximately 1200 lbs. ground corn per head while on pasture made an average daily gain of 2.15 lbs., sold for $3.89 more per cwt. and were decidedly more profitable. Other steers were grazed on pasture alone until mid-August or until October 30 and then short fed in dry lot. Each method of feeding was more profitable than fattening on pasture alone but less profitable than grain feeding on pasture. In the second series of trials calves were purchased in the fall, wintered with and without grain, then pastured without grain until mid-August and finished in dry lot. These steers were more profitable than the yearling steers purchased in the spring that were similarly fed during the grazing and finishing periods.

COMPARING SYSTEMS OF EARLY LAMB PRODUCTION INCLUDING PASTURE VERSUS ROUGHAGE FOR WINTERING EWES AND CREEP FEEDING VERSUS NO GRAIN FOR LAMBS. C. V. Ross and A. J. Dyer, *University of Missouri.*

Strong lambs were produced by 26 Northwestern ewes, which during pregnancy had only bluegrass pasture except during periods when weather conditions made it impossible for them to graze. Twenty-six similar ewes fed solely on legume hay and oat straw in dry lot produced lambs slightly smaller than those produced by ewes on pasture. The difference in weight was not statistically significant. Neither was there a significant difference in the gains made by the two lots of ewes during pregnancy nor in the fleece weights. A few abnormalities occurred among ewes wintered in dry lot: one lamb was born without a lower jaw and three ewes aborted. Of those aborting, one died. Analysis for vitamin A revealed an adequate amount stored in the liver. Half of the total number of lambs from each group of ewes was fed grain in a creep on pasture and the remainder had no grain. Creep fed lambs were heavier at marketing time, showed more bloom, and graded higher on foot and in the carcass. Forty-four percent of the creep fed lambs and thirty-five percent of those not receiving grain were marketed by June 19. By August 13, ninety-six percent of the creep fed lambs had been marketed while only fifty-eight percent of those not creep fed had been marketed.

METHODS OF SUPPLYING PHOSPHORUS TO CATTLE. L. H. Tash, J. M. Jones, and W. H. Black, *Experiment Station, Texas A. & M. College, and United States Department of Agriculture.*

A test to determine methods of supplying phosphorus to range cattle proved that the use of bonemeal in self-feeders; the use of a soluble phosphate in the water supply; and pasture fertilization, provided ample moisture is received, will prevent aphosphorosis. Weaning weights of calves from cows that received supplement, or that were grazed on a pasture fertilized with superphosphate, averaged from 50 to 60 pounds more than of calves from cows that received no additional phosphorus. Cows at the time the calves were weaned averaged over 200 pounds more for the groups receiving additional phosphorus. The history of the control group was characterized by numerous cases of extreme aphosphorosis among the lactating cows, low inorganic phosphorus content of the blood, failure to attain maximum development, and reduced fertility. Of the supplement-fed groups there was some advantage in favor of the group receiving a soluble phosphate compound through their water supply over the group receiving bonemeal. The pasture fertilized with 200 pounds of triple superphosphate per acre was stocked at a 50 percent higher rate than the pasture utilized by the other groups. This

group initially made the best record, then, as grazing conditions became progressively worse, the inorganic phosphorus content of the blood of the lactating cows dropped to about the same low level as that in the blood of the lactating cows of the control group. The cattle lost weight rapidly and numerous symptoms of aphosphorosis appeared.

BALANCED NUTRITION FOR RANGE LIVESTOCK—EMPHASIZING VITAMIN A. R. C. Tom, *Ralston Purina Company.*

For many years the need of vitamin A for range livestock has been recognized. Repeated experiments under controlled conditions, accompanied by numerous field demonstrations under practical ranching conditions have given uniformly satisfactory results with a practical vitamin A carrier during more than three years. One group of experiments conducted under practical range conditions during the wintering period of 1946–1947 resulted in 41 lbs. more for each cow and 17 lbs. more for her calf (approximately six weeks old) when a supplement fortified with vitamin A was fed and compared with a standard high-protein supplement. In the Rocky Mountain region early spring calves were produced satisfactorily when a supplement fortified with vitamin A was fed during the last two months of pregnancy and for thirty days after calving.

Physiology Section

F. N. Andrews, *Chairman*

IODINE DEFICIENCY IN NEWBORN SHEEP AND SWINE. F. N. Andrews, C. L. Shrewsbury, C. Harper, C. M. Vestal and L. P. Doyle, *Purdue University Agricultural Experiment Station.*

Considerable difference of opinion exists in the literature as to whether domestic animals in Indiana and neighboring states should receive supplementary dietary iodine. The gross and microscopic anatomy and iodine content of the thyroid glands of over 300 newborn lambs and more than 400 newborn pigs in three central Indiana sheep flocks and two swine herds were studied. Pregnant ewes and sows were fed commonly-used rations with and without iodized salt and observations were made over a three-year period. The normal thyroid of the newborn lamb is reported to weigh between one and two grams and to contain between 0.2 and 0.3 percent iodine on a dry weight basis. Of 234 lamb thyroids from ewes fed commonly-used rations not supplemented with iodine, 55 percent weighed more than two grams and only three percent contained more than 0.2 percent iodine. Only 12 percent of the glands appeared normal histologically. Similar increases in thyroid size, reductions in iodine content, and histological changes were observed in newborn swine. The use of stabilized iodized salt reduced the occurrence of these changes. The commonly recognizable clinical evidences of iodine deficiency such as hairlessness and scanty wool were not common. Correlations of 0.321 and 0.350 between iodine content and thyroid weight were found in lambs and pigs respectively. The correlations between iodine content and height of the thyroid epithelium were 0.646 and 0.525 in lambs and pigs respectively.

EFFECTS OF DILUTION ON MOTILITY OF BULL SPERMATOZOA. P. L. Cheng, L. E. Casida and G. R. Barrett, *University of Wisconsin.*

Visual estimates at 450 magnifications have been made of the percentage of spermatozoa showing forward motion in a dilution of 1:10 and in eight successive dilutions from 1:100 to 1:12800. Six semen samples from each of five bulls have been studied and two different diluents, 0.08M sodium citrate and 0.9% sodium chloride have been compared throughout. Average differences were shown in the motility of the spermatozoa from different bulls and in the different samples from the same bull. The percentage of motility decreased markedly in the higher dilutions but this decrease seemed fairly uniform for the different samples both within and between bulls and in the two different diluents. There was an average difference between the diluents, the motility being greater in the sodium chloride. The difference between the diluents, however, was more marked for some bulls and for some samples than for

others. Possible correlations have been sought between different indices of motility and the fertility of these samples of sperm when used in artificial insemination. No correlation was found between any index of motility when studied between samples within bulls. There was slight evidence for a correlation, however, between motility at a dilution of 1:10 and fertility and also between highest dilution in which motility was shown and fertility when studied between bulls.

EXPERIMENTAL USE OF COMMERCIAL HORMONE PREPARATIONS IN TREATING SHY-BREEDING DAIRY COWS. H. P. Davis, J. A. McCrory and A. B. Schultze, *University of Nebraska.*

Cows in the University herd requiring more than three services for conception and free of genital disease or infection were treated with Gonadin or Fulletein. Similar shy-breeders were not treated and served as controls. The conception rate of the untreated cows was 33 percent for 79 services over three. Cows for which the cause of shy-breeding could not be diagnosed from their breeding history or by examination of the genitalia were treated indiscriminately with Gonadin or Follutein. Neither preparation was effective in increasing the conception rate in such females (32 services). Cows and heifers found to have abnormally small and apparently underactive ovaries, although having fairly regular estrous cycles were treated with Gonadin. Seven of eleven treated services resulted in conception. This treatment was apparently more effective in heifers than in cows. Seven females diagnosed as having follicular cysts from the frequency of estrus and the presence of large follicular cysts were injected with 10,000 units of Follutein. All returned to regular estrous cycles but only five became pregnant. Eight females diagnosed as having greater than normal follicular development at estrus but not large enough to be classified as cystic and having normal estrous cycles were injected with 3,000 units of Follutein three days after service. Five of the eight conceived on the treated service. Of the 26 services in which abnormal function was indicated by examination, 17 conceptions resulted or a conception rate of 64 percent was obtained.

ADDING DRUGS TO THE RATION OF FATTENING CATTLE. M. E. Ensminger, E. A. Kline, W. W. Heinemann and T. J. Cunha, *State College of Washington.*

Forty head of yearling heifers grading good are being used in feeding trials designed to determine the effects of two stimulants, namely: Lot II—Fowler's Solution (arsenious acid); Lot III—Nux Vomica (a strychnine compound); and Lot IV—Thiouracil. Two bulls are being used to breed the heifers, each bull breeding five heifers in each lot. The effects from the use of the stimulants is being measured by the following criteria: gains; estrous cycle; services per conception; density, length, and luster of hair; physiological and pathological effects on the reproductive organs, heart, liver, kidneys, and thyroid glands; and carcass grade. The following average daily gains were made during the first 44 days of the trial: Lot I (control), 2.92 pounds; Lot II, 2.97 pounds; Lot III, 3.34 poonds; and Lot IV, 3.24 pounds. However, at the end of 156 days on trial the gains in all lots of heifers were about the same. The heifers will be continued on feed for another 42 days. Results to date on two years work indicate that the use of thiouracil, Fowler's solution, and Nux Vomica may be effective in increasing rapidity of gains only for a short feeding period. No harmful effects were noted in rat growth trials last year when the meat and internal organs of heifers fed thiouracil and the two druga (after a 40 day depletion period) were fed at a 30 and 80-percent level of their diet. Rat trials will be conducted this fall with the meat and internal organs of heifers, but with no drug depletion period prior to slaughter.

INFERTILITY (STERILITY) OF BEEF AND DAIRY COWS AND OUTLINE OF TREATMENT. A. H. Frank, *United States Department of Agriculture.*

Work on relative infertility in beef and dairy cows has been in progress for about one year. During this time records have been kept on more than 1000 cows. Over 50 percent of these cows have needed treatment for breeding troubles. Preliminary to treatment the cows were examined for known conditions such as improper development, abnormal growth, brucellosis, trichomoniasis and other pathogenic conditions of the genitalia that may interfere

with fertility. After elimination of the above maladies, the cows were classified according to their breeding behavior. The treatment was directed toward glandular dysfunction. Each class was treated by three different methods, mechanical (removal of corpora lutea and cysts and massage of ovaries), mechanical in combination with hormone (pregnant mare's serum), and p.m.s. alone. A fourth animal was kept as a control. This work has not been carried on long enough to evaluate the effectiveness of the different methods of treatment.

A BIOLOGICAL METHOD FOR DETERMINATION OF THIOURACIL IN TISSUES USING RADIOACTIVE IODINE. A. L. Franklin, J. W. Boehne, III and T. H. Jukes, *Lederle Laboratories Division, American Cyanamid Company.*

The following experiment was undertaken to determine by a biological method the thiouracil level in muscular tissue after prolonged feeding and the rate at which it disappears from the tissue following removal of the supplement. Weanling Chester White pigs were used. The diet was supplemented with 0.2% thiouracil for a period of 34 days, and then it was removed from the ration. Some animals were sacrificed at the time the supplement was removed, and others one and three days later. Pooled, dried muscular tissue was thus obtained for three groups of animals. The thiouracil content of the dried tissue preparations was then determined by feeding it at a 50% level to rats and measuring the degree of depression of thyroid function as indicated by the thyroidal uptake of radioactive iodine. A standard response curve for rats was established by adding thiouracil to a similar diet. Without thiouracil the gland could accumulate about 1.3% of an administered dose of radioactive iodine per mg. thyroid weight per 100 gm. body weight; however when 5 to 10 mg. of thiouracil was added per 100 gm. diet this value decreased approximately 50% and at a level of 100 mg. per 100 gm. diet a depression of 89% was observed. By similar measurements with rats fed tissue from pigs which had received thiouracil it was found that the thiouracil level of the muscle meat of pigs after prolonged feeding of 0.2% thiouracil was 6 ± 3 mg. per 100 gm. but that after the removal of the thiouracil from the ration for one day the level dropped to 2 ± 1 mg. per 100 gm., and no detectable amount was present after 3 days.

GROWTH STIMULATION WITH REGARD TO THE ANIMAL'S OWN THYROID SECRETION RATE. Victor Hurst and C. W. Turner, *Missouri Agricultural Experiment Station.*

Earlier work from this station indicated the favorable influence of exogenous thyroxine or thyroprotein on the growth rate of mice. With the development of an assay for the rate of thyroid hormone secretion, we have observed that the thyroid secretion rate declines with age. Recently our work has indicated that in order to accelerate growth to the maximum it is necessary not only to administer thyroxine at the proper level above the animal's own thyroid secretion level, but also that this level must decline in proportion to the normal decline of the thyroid secretion rate with age. Young Rockland female mice were divided into eight groups; one control, one on 0.1% thiouracil, and the other six on 0.1% thiouracil plus levels of injected *DL*-thyroxine varying from dosages less than the animal's own thyroid secretion rate to those causing extreme hyperthyroidism. After a twelve week period, high levels of thyroxine retarded skeletal growth and body weight as compared to controls. In one group, animals continued on a high level for an additional seven weeks either died, failed to breed, or dropped dead young in all but two out of seventeen cases. With the thyroid secretion rate declining with age, a stimulating dosage level at one stage of growth later reduced body weight to normal when hyperthyroidism began to occur. Growth of animals on thyroxine dosages approximating the normal thyroid secretion rate did not differ from that of controls.

THE DEVELOPMENT OF HYALURONIDASE IN BULL SEMEN. James E. Johnston and John P. Mixner, *Rutgers University.*

The concentration of the enzyme hyaluronidase found in bull semen may be a factor in fertility since it has been shown that this enzyme can disperse the corona radiata cells which surround the ovulated mammalian ovum. Thus the transport (or secretion) of hyaluronidase by semen and the subsequent denudation of the ovum may be an important function of semen

immediately preceding the penetration of the ovum by a spermatozoon. As a preliminary to the study of the relationship of hyaluronidase concentration in semen to its fertility, it was necessary to determine the effects of both the length and the temperature of semen storage upon the hyaluronidase concentration of seminal plasma. In this connection it was found (1) that hyaluronidase is found in seminal plasma immediately following ejaculation; (2) that seminal plasma which was centrifuged and filtered to remove all spermatozoa showed no increase in hyaluronidase concentration when stored at either 37° C. or 5° C.; (3) that upon storing semen after ejaculation at 5° C. there was a gradual and considerable increase in concentration of hyaluronidase (as much as 400% increase in concentration in 144 hours) coincident with a drop from a semen motility rating of 3 to 1; and (4) that upon storing semen after ejaculation at 37° C. there was an extremely rapid and large increase in the concentration of hyaluronidase (as much as 645% increase in concentration in 72 hours) coincident with a drop from a semen motility rating of 3 to 0.

AN INVESTIGATION OF THE STAINING PRINCIPLE AND THE BACKGROUND STAIN IN THE DIFFERENTIATION OF LIVE FROM DEAD SPERMATOZOA. Dennis T. Mayer, Dale Squiers and Ralph Bogart, *Missouri Agricultural Experiment Station.*

In the majority of semen specimens from the bull, ram, stallion and boar varying percentages of the spermatozoa are dead. In addition in each specimen some of the live cells are physiologically abnormal and die during the early stages of storage. Previous publications from this laboratory have suggested the use of live-dead staining technique alone and in combination with the cold shock method for the quantitative determination of dead and physiologically abnormal spermatozoa. In the original staining method for the differentiation of live and dead spermatozoa, eosin was the staining principle and opal blue (Breslau) was the background stain. Since the opal blue has been unobtainable, this laboratory, after a thorough investigation, found that fast green FCF is a better background stain than the original opal blue. Eosin B (bluish) was originally used as the staining principle, but results of this investigation show that all of the halogen derivatives of fluorescein including eosin Y, erythrocin, and rose bengal will stain the dead spermatozoa. It was also shown that staining of the dead cells may not occur if the pH, osmotic pressure, and stain concentration vary from a relatively narrow range. Staining of dead spermatozoa does not occur if the stains are not in a solution containing highly ionizable salts. The new staining mixture is described and details of the method are given. The accuracy and repeatability of the staining technique are attested by the results of a series of quantitative determinations.

THE EXPERIMENTAL INDUCTION AND MAINTENANCE OF LACTATION IN GOATS WITH ESTROGEN-THYROID COMBINATIONS. Joseph Meites and C. W. Turner, *Missouri Agricultural Experiment Station.*

Estrogens have been employed successfully in initiating lactation in goats and cows, but have been considered ineffective for augmenting established lactation. Thyroid preparations can increase established production, but cannot initiate it. Since estrogens can stimulate pituitary lactogen secretion and mammary growth, while thyroid can speed up metabolic processes favorable to lactation, these together should be superior to either alone. Two grade Toggenburg goats which were nearing the end of lactation, were given diethylstilbestrol and thyroxine for ten-day periods at monthly intervals. Initially, these goats were producing 1.1 and 1.8 pounds of milk daily, respectively. Six months later, after four ten-day treatments, daily milk production had increased over 100 percent (to about four pounds each). This represented as much milk as these goats had produced a year previously, a few months after kidding. Two dry, multiparous goats, weighing about 120 pounds each, were fed three grams of dimethyl ether of diethylstilbestrol and 75 grams of thyroprotein (Protamone) per 100 pounds of grain. The daily intake of each goat was estimated at about 60 mgs. of estrogen and 1.5 grams of thyroprotein. Milking was begun after four months. An upward trend in production occurred for over eight weeks reaching between three and four pounds daily per goat, and persisting at this level for six more weeks. No loss in body weight occurred, despite continuous hormone feeding throughout the experiment.

STUDIES OF SOME BLOOD CONSTITUENTS AT TIME OF PARTURITION IN MASTECTOMIZED COWS. R. P. Niedermeier, Vearl R. Smith and C. K. Whitehair, *University of Wisconsin.*

Studies were initiated to ascertain whether the changes in certain blood constituents at time of parturition were the result of the initiation of lactation or physiological factors accompanying parturition. The mammary glands were totally ablated from five Jersey cows, of which one was a two-year-old. The two-year-old and a nine-year-old cow have calved since mastectomy. The blood levels prior and subsequent to parturition for total serum calcium, plasma carotene and vitamin A and fat were studied. In the aged cow at parturition there was a drop in total serum calcium, carotenoids, and plasma fat. There was no appreciable change in the plasma vitamin A level. In the two-year-old there was no appreciable change in the total serum calcium at parturition, but a drop occurred in the plasma carotene and vitamin A levels.

A STUDY OF THE ACID AND ALKALINE PHOSPHATASE LEVELS IN CONSECUTIVE SEMEN EJACULATES FROM BULLS. J. T. Reid, G. M. Ward and R. L. Salsbury, *Rutgers University.*

A study was made of the levels of acid and alkaline phosphatase in a series of semen ejaculates obtained consecutively as long as libido persisted and within a 30 minute period from 10 young bulls. The 10 bulls composed 2 feed groups. Group I received a simple concentrate mixture consisting largely of corn while Group II was fed a complex mixture containing supplementary vitamins and minerals. Both groups received the same hay. In 56 ejaculates the mean levels of acid and alkaline phosphatase were 170 (range 46 to 338) and 393 (range 97 to 3,459) units per 100 ml. of bull semen, respectively. The semen from Group II bulls contained markedly higher levels of both phosphatases than that from Group I. A high degree of correlation existed between the acid phosphatase level and the spermatozoa concentration of the semen produced by both groups (Group I, 0.902; Group II, 0.876). The following significant coefficients of correlation were found between the semen acid phosphatase level and some characteristics of Group II semen: initial motility, 0.675; initial pH, −0.606; decrease in pH upon incubation, 0.688 and volume, 0.458. No significant relationship existed between the enzyme and these characteristics of Group I semen. The level of alkaline phosphatase was not related to the characteristics of semen studied. However, as previously suggested, the results of this study further indicated that the blood is the immediate origin of semen alkaline phosphatase.

THE EFFECTS OF GONADOTROPHINS ADMINISTERED TO SOWS AT DIFFERENT STAGES OF THE ESTROUS CYCLE. T. Y. Tanabe, L. E. Casida and R. H. Grummer, *University of Wisconsin.*

The action of gonadotrophins when administered at two different stages of the estrous cycle was studied in 18 Chester White and Poland China sows. Treatment of the two groups was initiated either on the 4th day (luteal phase) or 15th day (follicular phase) of the estrous cycle, respectively. A single injection of 2000 I.U. of pregnant mare serum gonadotrophin was given for follicular stimulation on the 4th or 15th day, depending on the group, followed five days later by an intravenous injection of 1 gm.-equiv. of unfractionated sheep pituitary extract for ovulation. All sows were mated or inseminated at the time of the intravenous injection and slaughtered 48–56 hours later. Sows in the follicular phase showed a greater ovarian reaction to the standard treatment than did luteal sows. This was indicated both by the average number of ovulation points (25.3 vs. 13.0) and by the number of intact follicles (5.4 vs. 10.8). Fertilized ova were not found in any of the luteal sows although an average of 10.6 ova was recovered per sow. In the follicular group 19.6 ova per sow were recovered and of these 5.3 were fertilized. The results were variable, however, in that five of the nine sows had no fertilized ova. Treatment failed to incite estrus in the luteal sows, and it delayed the onset of estrus in eight of the nine follicular sows beyond the 21st day (four beyond the 23rd day).

INTERRELATION OF THE PITUITARY AND THE SEX HORMONES IN MAMMARY GLAND GROWTH. J. J. Trentin and C. W. Turner, *Missouri Agricultural Experiment Station.*

The nature of the pituitary factor responsible for mammary duct growth was investigated by the extraction and assay of cattle anterior pituitary tissue. The active factor was found to be associated with the protein fraction rather than the lipid soluble fraction. The possible identity of the mammary duct stimulating and mammary alveolar stimulating factors was investigated by comparison of the duct stimulating and alveolar stimulating activity of a series of anterior pituitary preparations and extracts. The ratio of the mammary duct unit to the mammary alveolar unit varied from 0.5 to 1.8 for a series of eight preparations ranging from fresh anterior pituitary tissue of pregnant and non-pregnant cows to highly purified extracts. Under the conditions of these experiments the relatively small variation in this ratio is taken as indicating no significant separation of duct stimulating and alveolar stimulating activity of anterior pituitary. Until such time as the two activities are separated it would appear logical to regard them as the result of the same pituitary factor or combination of factors. The response of the male mouse mammary gland to estrogen, progesterone, and combined estrogen and progesterone was investigated to determine if it would be possible to stimulate alveolar growth to the exclusion of duct growth. In no case was it possible to induce alveolar growth without first inducing duct growth. In the hypophysectomized male mouse estrogen was found to produce insignificant or no mammary stimulation while combined estrogen and progesterone caused a slight amount of duct growth.

FEEDING THYROPROTEIN (PROTAMONE) TO LIVESTOCK IN RELATION TO THYROID SECRETION RATE. C. W. Turner, *Missouri Agricultural Experiment Station.*

The availability of thyroprotein, a synthetic hormone preparation permits the study by livestock physiologists of the possible beneficial effect of mild hyperthyroidism upon the rapidity of growth, reproduction, lactation and related economic factors in various breeds and classes of livestock. Where possible it is helpful to determine the average thyroid hormone secretion rate of each class of animals, then administer amounts of thyroprotein slightly in excess of the normal to determine the value of the hormone when present in increasing amounts. When thyroprotein, in excess of the normal amount secreted, is fed it has been observed to cause the animal's own thyroid to cease secretion. It is important, therefore, to withdraw the thyroprotein-feeding gradually so that the animal's own thyroid can gradually take over secretory activity again. However, if rapid fattening is desired, then abrupt withdrawal should be practiced. In the light of work conducted today the following comments may be made. For growing animals the incorporation of the thyroprotein as a percentage of the feed is better than feeding a definite amount per day. Requirements of both feed and thyroprotein increase with body weight. For lactating animals, the thyroprotein should be fed in relation to body weight rather than to milk production. To date no experimental evidence is available which suggests that increased productivity induced by mild hyperthyroidism is not compatible with long life. In our laboratory, White Leghorn hens have finished their sixth laying year. Each year their egg production has far exceeded the controls with a smaller mortality rate. The average production of the hens fed thyroprotein continuously for the past three years is actually greater this year than of the two previous years.

THE INFLUENCE OF THYROPROTEIN, THIOURACIL AND BREED ON GROWTH AND THYROID CHARACTERISTICS IN SWINE. D. P. Wallach, W. N. McMillen, H. W. Newland and E. P. Reineke, *Michigan State College.*

In continuation of the work reported last year, thyroprotein was fed to four breeds of growing pigs allotted against suitable controls, and its effect on growth and feed consumption were recorded. The pigs were self fed a growing ration and had access to rape pasture. While eight control Duroc Jersey pigs averaged 1.42 lbs. daily gain on 3.63 lbs. of feed per lb. of gain during a 79 day post-weaning period, two separate lots of seven Durocs receiving 1.4 and 2.8 gms. of thyroprotein per 100 lbs. of feed respectively, gained 1.54 lbs. daily on an average of

3.4 lbs. of feed per pound of gain. Lots of Yorkshires and Chester Whites receiving thyroprotein at the 2.8 gm. level were slightly more efficient and gained more rapidly than their controls. Berkshire pigs receiving 5.6 gm. of thyroprotein per 100 lbs. of feed made 0.28 lbs. more gain daily on 0.94 lbs. less feed per pound of gain than their controls. Improvement in quality of hair coat was noted in all groups receiving thyroprotein. A corollary study on the weight and histology of thyroids from Berkshires, Duroc Jerseys, Yorkshires, and Duroc × Yorkshire Crossbreds was made, and revealed significant differences between the different breeds both in gross histology and mean acinar cell height. The possible correlation between thyroid histology and market type will be discussed. It has been demonstrated that thyroprotein administration produces a histologically inactive gland, and thiouracil produces extreme hypertrophy and hyperplasia.

OCCURRENCE OF POSTPARTUM ESTRUS AND OVULATION IN SOWS. A. C. Warnick, L. E. Casida and R. H. Grummer, *University of Wisconsin.*

Sows were checked daily for heat beginning 1 day postpartum. Sows that came into estrus were bred and killed 1 to 2 days postestrum; sows that did not show heat were killed 10 days postpartum. Twenty-one sows were studied during the interval from April, 1946 to February 1947. Six of 19 suckled sows came into heat and were bred within 4 days postpartum. None of these sows ovulated and none had follicles above 5 mm. in diameter. Thirteen suckled sows did not come into heat by the tenth day and none ovulated. Two nonsuckled sows (pigs dead at birth in one case and immediately after birth in the other), came into heat by the seventh day and 8-cell embryos were flushed from the oviducts. A second experiment was run during the interval from May to July, 1947 to study the effects of suckling. Eight suckled and 7 nonsuckled sows were checked for heat by the same method as in the first experiment. The young were removed at birth from the 7 nonsuckled sows. Five of the suckled and 5 of the nonsuckled sows came into heat and were bred within 3 days postpartum but none ovulated. The remaining sows in each group which failed to come into heat also failed to ovulate by 10 days postpartum.

SOME GENITAL CONDITIONS ASSOCIATED WITH LOWERED FERTILITY IN SOWS. A. C. Warnick, R. H. Grummer and L. E. Casida, *University of Wisconsin.*

Thirty-one sows that had failed to conceive from breedings at 2 to 4 consecutive heat periods were obtained from Wisconsin swine growers for a study of causes of low fertility. All sows were mated to fertile boars at the first estrus after being obtained from the farmers. Sixteen sows were killed 1 to 2 days after the end of heat and are referred to as Group I; 15 sows killed approximately 25 days after breeding comprised Group II. Ten of the 16 sows of Group I showed normal pregnancy at 2 days; only 4 of the 15 of Group II showed normal pregnancy at 25 days. Structural abnormalities of the genital tract, embryonic death, pathology of the oviducts and cystic follicles were apparent causes of lowered fertility.

RELATION OF RETENTION OF FETAL MEMBRANES TO THE CONCENTRATIONS OF VITAMIN A AND CAROTENOIDS IN THE BLOOD SERUM OF THE DAIRY COW. G. H. Wise, D. B. Parrish, M. J. Caldwell, F. W. Atkeson and J. S. Hughes, *Kansas Agricultural Experiment Station.*

Postpartum studies of vitamin A and of carotenoids in the blood serum of dairy cows included 12 animals that retained fetal membranes and 20 that eliminated them within 6 hours after parturition. During the 28 days preceding the scheduled calving date, the experimental subjects were divided into 2 dietary groups, those restricted to a typical barn ration (concentrate mixture, alfalfa hay and Atlas Sorgo silage) and those receiving a similar ration supplemented with a vitamin A concentrate. The latter group received 500,000 U.S.P. units of vitamin A daily from 28 to 14 days preceding the expected day of parturition and 1,000,000 units daily during the remainder of the prepartal term. The postpartum ration was the same for all cows. As previously noted, the concentration of vitamin A in the blood serum of the cows continued to decrease several days following parturition, but after the first day, the rate

and duration of the decline were strikingly greater in the group that retained the placental membranes than in those that eliminated them normally. A distinct difference in the concentrations of vitamin A persisted through the seventh day even though the levels in all the cows were increasing at this stage. The prepartal dietary supplementation with vitamin A had no marked effect on the postpartum trends of vitamin A in the serum of the animals. The concentrations of carotenoids in the blood serum of the group retaining placentas declined more than in the case of the normal group but the magnitude of the difference was not so great as noted for vitamin A.

NEWS AND NOTES

Members are reminded that the annual meeting of the American Society of Animal Production will be held at the Hotel Sherman in Chicago on November 28 and 29, 1947, with a dinner for the honor guest on November 30. Abstracts of the papers to be presented at this meeting are included in this issue of the JOURNAL OF ANIMAL SCIENCE.

The Fifth International Grassland Congress will be held in Holland during the summer of 1949. Mr. P. V. Cardon, Special Assistant to the Chief of the Bureau of Plant Industry, Beltsville, Maryland, will act as Liaison Official between the U. S. Department of Agriculture and the Congress. Dr. O. S. Aamodt, also of the Bureau of Plant Industry, will act as alternate to Mr. Cardon. As the program develops, the various federal and state agencies, and the interested societies will be advised.

A nation-wide conference on the use of radioactive isotopes in agricultural research is to be held December 18-20, 1947 at Alabama Polytechnic Institute, Auburn, Alabama, in cooperation with the Oak Ridge Institute of Nuclear Studies. The three-day meeting, which will include lectures by some of the country's foremost investigators in the field, will be the first to be held in the world on the application of radioactive materials to agricultural research. Some 300 scientists from all sections of the United States are expected to attend. One section of the program will be devoted to the use of radioactive materials in nutrition and animal husbandry research. Lecturers in these fields include Dr. G. Harold Copp, radiation laboratory, University of California School of Medicine, Berkeley; Dr. Howard B. Skipper, Southern Research Institute, Birmingham, Ala.; and Dr. J. G. Davis, animal husbandry department, University of Florida, Gainesville. The first day of the conference will be concerned with fundamentals, while the second day will be devoted to use of radioactive materials in the research fields of plant physiology, soils, and horticulture and to laboratory demonstrations of typical tracer experiments. Room and meal accommodations of the Alabama Polytechnic Institute campus have been arranged for the conferees.

L. A. Maynard, of Cornell University, has prepared a second edition of his book, "Animal Nutrition." Extensive revisions have been made in all chapters in order to bring the book abreast with advances in research on the chemistry and physiology of nutrition during the past decade. Recent developments regarding amino acid, vitamin and mineral nutrition are presented, and the discussions of copper, manganese, magnesium and cobalt have been greatly expanded. Opening with a chapter on the expanding field of nutrition, the author then deals with the animal body and its food, physio-chemical bases of life processes, carbohydrates, lipids, proteins, inorganic elements and their metabolism, vitamins, feeding experiments, determination of digestibility, nutritional balances, measures of food energy, fasting catabolism, growth, reproduction, lactation and work production. Selected literature citations are included for the convenience of the student. The book was published by McGraw-Hill Book Company, Inc., New York, N. Y. It contains 494 pages, and the price is $5.00.

A book entitled "Beef Cattle Husbandry" by F. W. Farley was published recently by The Stockman, Memphis, Tennessee. It consists of a combination of revisions of two former books by the author, entitled "Hereford Husbandry" and "Raising Beef Cattle on Farm and Range." It contains chapters on classification of beef cattle, foundations of the breeds, inheritance and

variation, selection and mating, the pedigree, fundamentals of feeding, problems in breeding, handling, a registered herd, fitting and showing, advertising and selling, raising commercial beef cattle, marketing commercial herd produce, feeding beef cattle for the butcher, marketing fat cattle, dehorning, castrating, care of feet, and diseases, insects and parasites. A separate article by V. A. Rice, on "The Freemartin," is also included. Advertising is interspersed with the textual material. The book contains 286 pages, including advertising material.

"Sheep Science," by W. G. Kammlade of the University of Illinois, was recently published by the J. B. Lippincott Company. This is a new text covering all phases of the sheep and wool industry and it is designed primarily as a college text.

Fred F. McKenzie of Oregon State College, John Hammond of Cambridge University, and F. T. Day of Newmarket, England, were members of the instructing staff of a school on artificial insemination and sterility, held at the Instituto Sperimentale Italiano "Lazzari Spallanzani" in Milan, Italy, from August 4 to August 15, under the sponsorship of the Food and Agriculture Organization of the United Nations. Workers from twelve countries were in attendance.

Y. Z. Tang of the Animal Husbandry Department, National Central University, Nanking, China, accepted a one-year assignment with the Animal Industry Branch, Agriculture Division, Food and Agriculture Organization of the United Nations, Washington, D. C., effective July 15.

N. R. Joshi, of Nagpur, India, who has been dairy development officer for the Central Provinces and Berar, has accepted a position as animal breeding specialist in the Animal Industry Branch, Agriculture Division, Food and Agriculture Organization of the United Nations, Washington, D. C.

Ralph W. Phillips, of the Food and Agriculture Organization of the United Nations, was in Europe during August and September attending the annual conference of the Organization in Geneva, and also traveling in Italy and England on behalf of the Organization.

L. A. Henke, of the Agricultural Experiment Station at the University of Hawaii, served as Visiting Professor at the University of Puerto Rico during the second semester of 1946–47 while on leave from his regular post.

W. W. Green, of the University of Minnesota, is serving as Visiting Professor of Animal Husbandry at the University of Puerto Rico, Rio Piedras, P. R., for one year while on leave from his regular post.

James H. Bywaters joined the staff of the Virginia Agricultural Experiment Station on August 1 where he will plan and conduct poultry research. Dr. Bywaters has been on the staff of the Regional Poultry Laboratory at East Lansing, Michigan, for the past several years.

Charles I. Hobbs has resigned as head of the animal husbandry department at South Dakota State College, to accept a similar position at the University of Tennessee.

Leslie E. Card has been made head of the Animal Science (formerly animal husbandry) department at the University of Illinois, succeeding W. E. Carroll who has assumed broader administrative duties.

A. O. Shaw has resigned as head of the animal husbandry department at the University of Maine, to become head of the dairy husbandry department at Washington State College.

L. A. Richardson, extension animal husbandman at the University of Tennessee for the past 28 years, died suddenly on September 8 while on a vacation trip at Parkersburg, West Virginia.

Meade T. Foster is being transferred from his post as agricultural attache with the U. S. Embassy at Ottawa, Canada, to a similar position at Wellington, New Zealand.

Sam I. Williams has returned to his position of assistant extension animal husbandman at the North Carolina State College after an extended period of military service in Europe.

George W. Stiles, who for 45 years was an animal disease specialist with the U. S. Bureau of Animal Industry, retired from public service in July. For nearly 30 years of that time he was in charge of the pathological laboratory at Denver, Colorado.

R. H. Lush recently resigned his position with the National Fertilizer Association in Washington, D. C., to accept a position as professor of dairying at the University of Tennessee.

Arless A. Spielman, associate professor of animal husbandry at Cornell University, has been made head of the animal husbandry department at the University of Connecticut.

Russell Coleman has been named director of the Mississippi Agricultural Experimental Station, succeeding Clarence Dorman who died in February. Frank J. Welch, who is dean of the Agricultural College was made associate director of the station at the same time.

Guy A. McDonald, former extension animal husbandman, South Dakota State College, and more recently field representative with the National Committee on Boys and Girls Club work, is now with the public relations department of the National Livestock and Meat Board in Chicago.

Thomas B. Keith, recently on the Montana State College staff, is now associate in animal husbandry at the University of Idaho.

H. M. Vollrath, assistant extension animal husbandman at the University of Hawaii, is now on sabbatic leave, and is taking graduate work at the University of Minnesota. A. M. Hironamus is substituting for him in Honolulu.

Wilton L. Finley has been appointed extension specialist in animal husbandry at Michigan State College to succeed E. L. Benton, deceased.

W. H. Bruner has been made secretary of the Ohio Wool Growers' Cooperative Association at Columbus, succeeding L. A. Kauffman who joined the animal husbandry staff at Ohio State University.

George E. Strum, former county agent in the North Dakota Agricultural Extension Service, has been appointed assistant extension livestock specialist in the same organization with headquarters at Bismarck.

H. G. Zavoral, extension animal husbandman, University of Minnesota, Joseph Muir, extension animal husbandman, Washington State College, and A. L. Anderson of the animal husbandry staff, Iowa State College, were members of a group making a two-weeks educational tour in October under the sponsorship of Swift and Company.

A liberal appropriation by the Louisiana State Legislature has permitted expansion in the livestock program at Louisiana State University. A portion of the money appropriated is being used to improve the livestock at L.S.U. and the remainder to establish an artificial breeding service for the state. In the latter program, the laboratory and bull stud will be located at the University and semen will be furnished free (as long as finances are available) to the local units of the recently organized Louisiana Artificial Breeding Cooperative, Inc.

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